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M I N U T E S   A N D   P R O C E E D I N G S

of the twentieth meeting of the

ARMY - NAVY - NRC VISION COMMITTEE

October 20-21, 1947

Special Devices Center
Port Washington, Long Island, New York

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Minutes of the Twentieth Meeting

October 20-21, 1947

Special Devices Center
Port Washington, Long Island, New York

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- Dr. Louise L. Sloan, Johns Hopkins University
- Mr. Arnold M. Small, Navy Electronics Laboratory, San Diego
- Dr. Donald G. Marquis
- Dr. H. Richard Blackwell

Monday Morning, October 20, 1947 Page

1. Captain George M. O'Rear, Director of Special Devices Center, welcomed members and guests of the Vision Committee to Special Devices Center.

2. Captain C. W. Shilling, Chairman of the Vision Committee, opened the meeting by calling for corrections in the Minutes and Proceedings of the 19th meeting. There were no corrections.

3. The Chairman asked that an abstract of a report presented by Miss Dorothy Nickerson, Secretary, Inter-Society Color Council, at the 19th meeting, be read into the Minutes to supplement the abstract contained in the Proceedings of the 19th meeting.......... 15

4. The Chairman Called upon Dr. Walter R. Miles to read the following memorial to Dr. Selig Hecht.

   Resolved that in the death of Dr. Selig Hecht, Professor of Biophysics at Columbia University, on September 18, 1947, visual science, not only in the United States but throughout the world, has suffered an irreparable loss. His fundamental contributions to this broad field were manifold. Among them the following must be listed: early work on lower organisms which gave rise to his fruitful formulations on the kinetics of photo-reception; his validation of many of these ideas in direct studies of visual purple; his redetermination of many basic visual functions through the application of improved biophysical techniques and creative theoretical thought; his imaginative theoretical treatment and attack on color vision; and his resolution of the problem of the quantum relations in the photo-sensory process. Our understanding and experimental control of basic facts of visual science have been advanced immeasurably by the results of his creative imagination combined with intellectual clarity and honesty.

   Dr. Hecht's contributions as a scientist were by no means restricted to his work in the laboratory. From the beginning of the recent war he gave unsparingly of his time and knowledge to the solution of a wide range of military problems. He served as a distinguished member of our Committee and of other national advisory committees. He was counselor and expert consultant on numerous occasions and directed many researches, and individually conducted both field and laboratory investigations to answer specific critical military problems. At the end of the war he enthusiastically embraced the role of educator of the public in basic concepts and implications of atomic energy. The role of educator was not new to him, he had long been recognized as a great teacher effective in training and stimulating workers in diverse scientific fields. As colleague, friend, and critic, he was unique and has left an impress both personal and scientific that will endure.

It was moved and seconded that the memorial be incorporated in the Minutes and Proceedings, and that a copy be sent to Mrs. Hecht. The motion was carried by a rising vote.

The Executive Secretary has received the following note from Mrs. Hecht:

> "Mrs. Selig Hecht is deeply grateful for your kind message of sympathy and for the beautiful flowers."

5. Dr. Morris S. Viteles presented a paper on the Ohio State study of visual standards for pilot selection.................. 17

6. Dr. Robert J. Wherry presented a paper entitled "The Army Visual Acuity Research Program"................................ 35

7. The Chairman moved that the Committee forward a letter of commendation to the Adjutant General concerning the visual acuity testing program. The motion was seconded and unanimously voted by the Committee. Copy of the letter is found in the Proceedings......... 47

8. The Chairman requested that the Minutes of the meeting of the Subcommittee on Visual Standards, held August 26, be read into the Minutes of the meeting...................................... 49

9. Dr. Richard G. Scobee, Chairman, Subcommittee on Visual Standards, presented recommendations on visual standards for the Armed Services.. 51

10. Dr. Scobee presented Subcommittee recommendations for a visual screening device.. 57

11. The Chairman called for acceptance of the recommendations of the Subcommittee on Visual Acuity. It was the sense of the meeting that the recommendations be accepted.

12. The Chairman requested that it be reported in the Minutes and Proceedings that the NRC Committee on Ophthalmology has approved the "Manual of Instructions, Testing Visual Acuity" and recommended that it be adopted by the Armed Services.

    The Chairman asked the Executive Secretariat to forward the manuals "Testing Visual Acuity" and "Testing Heterophoria" to the Surgeons General.

13. Dr. Fred A. Hitchcock discussed the proposed Vision Research Institute at Ohio State University.................................. 59

14. Dr. H. Richard Blackwell presented a paper entitled "Report of the Roscommon Visibility Tests"................................ 65

15. Commander R. T. Alexander presented a report on problems of visibility in the Coast Guard.................................. 75

ABSTRACT OF MISS DOROTHY NICKERSON'S

REPORT ON THE FUNCTIONS OF THE INTER-SOCIETY COLOR COUNCIL

Miss Nickerson outlined the history of the Inter-Society Color Council, whose formation arose from the need for a "horizontal" organization cutting across the many societies concerned in various ways with color and color vision. She named past chairmen of the Council and discussed some of the more dramatic activities of the organization. She reported that at the present time the I.S.C.C. has 13 member bodies* with 110 appointed delegates, and about 140 individual members. These individual members sometimes represent interests not organized into societies, but more often they are members but not delegates of one or more of the member bodies which belong to the Council.

Miss Nickerson reported that aims and purposes of the Council, as quoted from its Articles of Organization and Procedure are "to stimulate and coordinate the work being done by the various societies, organizations, and associations leading to the standardization, description, and specification of color, and to promote the practical application of these results to the color problems arising in science, art, and industry." These broad aims are achieved through meetings of the Council, with technical, discussion, and business sessions, and through general clearing house activities of the Problems Committee. On recommendation of this committee problems that seem to warrant individual study may be referred to a special subcommittee formed for the purpose.

Copies of a booklet describing the Council's organization in more detail were furnished by Miss Nickerson. In addition, copies of a typical bimonthly mimeographed News Letter were furnished. Through the News Letter notices, new facts and applications, and bibliography are circulated to delegates and members. Copies of these publications are in the files of the Vision Committee and can be loaned upon request.

* ISCC MEMBER BODIES:

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American Pharmaceutical Association, National Formulary
American Psychological Association
American Society for Testing Materials
Federation of Paint and Varnish Production Clubs
Illuminating Engineering Society
Optical Society of America
Society of Motion Picture Engineers
Technical Association of the Pulp & Paper Industry
The Textile Color Card Association of the United States, Inc.
U. S. Pharmacopoeial Convention

VISUAL STANDARDS AND FLIGHT PERFORMANCE

by

Morris S. Viteles, Ph. D.

Professor of Psychology, University of Pennsylvania;

Chairman, National Research Council Committee on Selection and Training of Aircraft Pilots.

Acknowledgments: The investigation described in this report was conducted under the direction of the National Research Council Committee on Selection and Training of Aircraft Pilots as a cooperative effort. It is not the work of the author of this paper or of any single individual. The study was initiated at the request of Dr. D. R. Brimhall, Assistant to the Administrator for Research, Civil Aeronautics Administration, following inquiries as to the possibilities of such an investigation from the Civil Aeronautics Board. The study was designed by a Committee on the Visual Study of the Committee on Selection and Training of Aircraft Pilots, including Dr. W. R. Miles, Chairman, Dr. J. C. Flanagan, Dr. Raymond Franzen, Dr. Peter Kronfeld, and Dr. M. S. Viteles. Dr. Peter Kronfeld and Dr. W. O. Fenn, representing National Research Council Committee on Medical Problems of Civil Aviation, and Lt. Col. John L. Matthews from the Aero-Medical Association helped in defining the limits for the visual groups and in planning the visual tests and the ophthalmological examination. Dr. P. J. Rulon, a member of the Executive Subcommittee of the Committee on Selection and Training of Aircraft Pilots, and Dr. Raymond Franzen acted as special consultants on the statistical aspects of the study. The investigation was conducted at the School of Aviation, Ohio State University, under the general supervision of Dr. Floyd C. Dockeray, with the assistance of Dr. G. Gorham Lane and Mr. David Bakan. The details of the ophthalmological examination were formulated by Dr. Peter Kronfeld, and the administration of the visual tests was supervised by Dr. Glenn A. Fry, Ohio State University. Brigadier General E. G. Reinartz, AAF School of Aviation Medicine, cooperated in making available the services of a staff ophthalmologist, Col. M. J. Reeh. In general, the study was in every sense a cooperative effort, involving the collaborations of psychologists, physiologists, ophthalmologists, and medical practitioners, using funds provided through the Division of Research, Civil Aeronautics Administration.

The purpose of this paper is to discuss an investigation designed to determine the relationship between visual measures and flight performance. This experiment was undertaken by the Committee on Selection and Training of Aircraft Pilots at the request of the Civil Aeronautics Administration.

The investigation was centered primarily on visual acuity. Stated positively, the hypothesis which the experiment was designed to test is this:

> Other things being equal, persons with various degrees of visual deficiency will learn to fly as well as persons with nominally "perfect" vision.

One of the first questions which arose in designing the experiment to test this hypothesis was whether to use (a) subjects giving a continuous distribution of visual efficiency, from no defect to serious defects, throughout the entire range of visual acuity, or (b) groups of subjects, each with a defined range of visual acuity, representing levels of visual efficiency.

The second alternative seemed best suited for this investigation and it was decided to use groups of subjects, representing levels of visual efficiency suitable for revealing such differences in flight performance as may be associated with visual deficiency.[1] These include a control group with "Normal" uncorrected vision and three experimental groups with varying degrees of visual defect, as follows:

1. <u>Group A</u>: Unaided vision of 20/20 or better in each eye with a high acuity of stereopsis and a refractive error under cycloplegia of less than 0.50 D. of myopia in any meridian, 1.50 D. of hyperopia in any meridian and 1.00 D. of astigmatism.

2. <u>Group B</u>: Unaided vision of 20/50 or worse in each eye corrected with forward glasses to 20/20 or better in each eye, with a high acuity of stereopsis corrected (3 cm. at 6 meters) and a refractive error under cycloplegia of less than 3.00 D. in any meridian, less than 2.00 D. of astigmatism and less than 2.00 D. of difference between any parallel meridians in the two eyes.

3. <u>Group C:</u> Unaided vision of 20/100 or worse in each eye corrected with forward glasses to 20/50 or better in each eye, with a corresponding acuity of stereopsis (10 cm. at 6 meters) and a refractive error under cycloplegia exceeding 4.00 D. in any meridian.

4.(a) <u>Group D:</u>[2] One eye correctible to 20/20 with a refractive error less than 3.00 D. in any meridian and less than 2.00 D. of astigmatism; the other eye uncorrected 20/100 or worse not correctible to 20/50, or having been removed at least 5 years prior to application for flight training.

(b) Group D_2: Same as D_1 except that the candidate must also be a squinter.

(c) Group D_3: A 10° of greater horizontal tropia with less than[3] 10° of vertical tropia and with each eye correctible to 20/20 with a refractive error less than 3.00 D. in any meridian and less than 2.00 D. of astigmatism.

Candidates in group A did not wear glasses during the period of flight training, whereas subjects in other groups wore glasses as prescribed by the ophthalmologist.

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1. The second alternative seemed best becuase one of the requirements for the groups can be so formulated as to provide different degrees of visual defect for comparison in terms of flight performance while, at the same time, relative economy in the number of subjects required can be achieved. In addition, an attempt to select subjects covering a continuous range of visual acuity is complicated by the fact that even though a continuum in terms of acuity might be set up, there would still be no assurance that a continuum existed in terms of defects associated with loss of acuity, that is, a continuum in terms of visual efficiency.

2. For purposes of the visual testing routine, Group D was divided into 3 sub-groups, D_1, D_2, and D_3. However, so far as the analysis of data is concerned, these sub-groups constitute the single classification, Group D.

In considering the grouping, it should be noted that Groups C and D include individuals who do not meet the current requirements of CAA for final certification as a private pilot without flight tests to supplement the medical examination.[3] These are what might be called basic experimental groups, with Group A as a basic control group of individuals with normal, uncorrected vision. Group B is of special interest in terms of individuals with defects correctible to a high level of efficiency although this group does not fit so clearly into the present CAA pattern of visual requirements for certification of private pilots.

Having defined the requirements for the experimental and control groups, it seemed of considerable importance to determine the proportion of individuals in the population as a whole falling into these various visual categories. An estimate of the proportion in each group, and of the proportion of the population falling in the gaps between groups, was made by the members of the Committee on Visual Study, under the chairmanship of Dr. W. R. Miles (Yale University), which served as the steering committee in working out the procedures and the statistical design of the experiment. Subsequently, a "revised estimate" was made by Dr. Peter C. Kronfeld (University of Illinois) who acted as a Consultant to the Committee on Selection and Training of Aircraft Pilots, as representative from the Committee on Medical Problems in Civil Aviation, with special reference to the visual classification and the ophthalmological examination. The original and revised estimates are shown in Table 1.

TABLE I

ESTIMATED PROPORTION OF TOTAL POPULATION FALLING INTO EACH VISUAL GROUP

		Original Estimate	Revised Estimate
	Group A	36.5%	50 %
Between	A and B	25 %	24.5%
	Group B	25 %	13 %
Between	B and C	6 %	3 %
	Group C	2.5%	3 %
Between	C and D	0.5%	2 %
	Group D	4.5%	4.5%

The statistical design of the experiment called for a total of 200 subjects, including 80 in Group A and 40 in each of the remaining three groups. Visual tests and an opthalmological examination were used in classifying candidates for flight training. These were administered at a Visual Training Center, directed by Dr. Glenn Fry, established at Ohio State University, where the experiment was conducted.

Applicants were first screened as to eligibility for the project through the use of the Ortho-Rater. Those passing the screening test were then referred to an opthalmologist[4] to:

[3] A large proportion of subjects in Group C had vision in both eyes correctible to 20/30. However, the ophthalmological examination revealed a good deal of refractive error for such subjects, pronounced differences between the two eyes, and other conditions which frequently require wearing thick corrective lenses.

[4] Ophthalmological examinations of early applicants were made by Col. M.J. Reeh, whose services were made available to the project through the courtesy of the AAF School of Aviation Medicine, Brigadier General E. G. Reinartz, Commanding. Subsequent examinations were conducted by local ophthalmologists.

a. determine the objective refraction under cycloplegia;
b. determine the results of the post cycloplegic test;
c. determine the prescription for the individual, if any;
d. give an appraisal of any disease;
e. make a diagnosis.

Following the opthalmological examination, an extensive battery of visual tests, including measures of stereopsis, peripheral vision, color blindness and others were administered at the Visual Testing Center. Visual test results and ophthalmological findings were then reviewed as a basis for classifying the applicant into one of the four visual groups in accordance with the fixed requirements for each group.

In addition, a number of psychological tests were administered. Of these, only the Ohio State Psychological Examination was used in determining eligibility for the experiment, the requirement being that the candidate's score on this test must be at the 15th percentile or above. Scores in the remaining psychological tests[5] have been used in determing whether the relationship between aptitude for flying and performance in learning to fly is such as to require analysis of covariance rather than analysis of variance in the treatment of results. Other requirements were that subjects be male, between the ages of 17 and 29, inclusive, high school graduates, and that each contribute $125 to the cost of training for the private pilot certificate.[6]

Subjects of the experiment were 194 men, including 80 in Group A; 38 in Group B; 40 in Group C, and 36 in Group D, who were given complete flight training, under the conditions of the experiment, at Don Scott Field, School of Aviation, Ohio State University, where the investigation was conducted under the immediate supervision of Dr. Floyd C. Dockeray with the assistance of Dr. G. G. Lane, and David Bakan. Subjects were selected, on the basis of the standards discussed above, from 843 applicants for flight training. Of the latter, 510 were disqualified or withdrew during preliminary screening activities, for reasons shown in Table 2. Another 77 withdrew during the period between the completion of screening procedures and the first day of flight training. Reasons for such withdrawals are shown in Table 3. A total of 12 subjects withdrew after training had started, but within a short enough period (less than 10 hours) to permit substitutions of entirely new subjects without interfering with the design of the experiment. The reasons for such withdrawals are shown in Table 4. There remained at the completion of the

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[5]Mashburn Serial Reaction Time Test, Two-Hand Coordination Test, Test of Mechanical Comprehension, Otis Test of Mental Ability, Desire-To-Fly Inventory, Test of Aviation Information, Biographical Inventory, and Ohio State Entrance Examination were the tests used. Correlations of these tests with criterion measures have proven to be uniformly low, and the indications are that the correction of the criterion measures in a covariance analysis would be extremely small. Treatment of results has therefore so far been confined to analysis of variance.

[6]The total cost of flight training, including 40 hours, was originally $275 which was later raised to $325. The difference between the amount paid by the student and the total training cost, including payment for flight hours in excess of 40 to a maximum of 50, was paid from research funds. In addition, 4 subjects in Group D received full scholarships. Moreover, in the case of approximately 85% of the students the share of the flight training cost paid by the students was actually paid by the government under the G. I. Bill of Rights.

experiment 50 applicants who had expressed a willingness to become subjects of the experiment, but who were not used as subjects because quotas had been filled.

The chronology of the investigation, with respect to the disposition of cases, is shown in Exhibit A. In passing, it is of interest to note that the percentage of withdrawals prior to training is significantly higher for Groups C and D combined as compared with Groups A and B combined (35.2% vs. 21.1%). These figures suggest the possibility that students with defective visual acuity are less motivated to fly than are those with unimpaired or slightly impaired visual acuity. On the other hand, on the basis of informal interviews with subjects, there is also some justification for the additional hypothesis that Groups C and D subjects were more influenced than were those in Groups A and B by comments made to them to the effect that they were endangering themselves in undertaking flight training.

TABLE 2

REASONS FOR DISQUALIFICATION OR WITHDRAWAL DURING PRELIMINARY SCREENING ACTIVITIES
N = 510

Reason	Number
Preliminary Visual Examination (Failed)	208
Lack of Interest*	206
Lack of Time	57
College Disapproval	12
Previous Flight Time	14
Over-age	7
Physical Examination (Failed)	3
Lack of Funds	3
	510

*Including failure to return after initial interview.

TABLE 3

REASONS FOR DISQUALIFICATION OR WITHDRAWAL DURING THE PERIOD BETWEEN THE COMPLETION OF SCREENING PROCEDURES AND THE FIRST DAY OF FLIGHT TRAINING
N = 77

Reasons for not Continuing	A	B	C	D	TOT.
Lack of Time	17	8	16	9	50
College Disapproval	1	1	2	1	5
Lack of Interest	4	7	4	5	20
Drafted	1		1		2
TOTALS	23	16	23	15	77

TABLE 4

REASONS FOR DISQUALIFICATION OR WITHDRAWAL AFTER
TRAINING HAD STARTED
N = 12

Reasons for not Continuing	A	B	C	D	TOT.
Lack of Time	2		2	2	6
Drafted		2			2
Airsickness	1		1		2
Emotionally Unstable	1				1
Physical Handicap	1				1
TOTALS	5	2	3	2	12

Subjects were given flight training in accordance with the requirements of a controlled course of primary flight instruction approved by CAA. The experiment was conducted over a period of six academic quarters. Each of the six successive classes, ranging in size from 25 to 39 included Groups A, B, C, and D subjects roughly in the ratio of 2:1:1:1, respectively. These were distributed as equitably as possible among the instructors within the limitations imposed by the available number of instructors and scheduling problems.

Each subject was put through a check flight by one of the check pilots following the 7th, 15th, 25th, and 35th hour of flight training. Following the 35th hour of flight training all subjects were given the private pilot flight test by a flight examiner or a flight inspector. All Group D subjects were given this flight test by a CAA flight inspector who, at the same time, gave the medical flight test as required under CAA regulations. Subjects failing the private flight test were given additional flight instruction to a maximum of 50 hours and when described as ready by their instructors were put through another flight check by the check pilot followed by another private pilot flight test given either by a flight examiner or a flight inspector. The maximum number of check flights for any subject was 6 and the maximum number of private pilot flight tests was 2.

Two airplanes were used for the check flights and there were two check pilots for each class. Planes and check pilots were counter-balanced with reference to the visual groups in order to overcome any bias that might result from plane or check pilot differences.

In Table 5 is presented a summary of data descriptive of flight performance collected during the investigation. These have yielded a large variety of criterion measures. To date, the analysis of the data has covered only 14 of these criterion measures, including Pass-Fail,

EXHIBIT A

DISPOSITION OF ALL CASES INVOLVED IN VISUAL STUDY

Applicants
843

On Hand
at end of
Program

50

TOTAL
= 50

Accepted
for
training

A = 101
B = 60
C = 63
D = 59

TOTAL
= 283

Disqualified

510

TOTAL
= 510

Variation in percentages of withdrawals significant at 1% level of confidence. Also significant at 1% level of confidence where A's and B's pooled, and C's and D's pooled.

Withdrew before begining training

A - 14 (13.9%) } 21.1%
B - 20 (33.3%)
C - 21 (33.3%) } 35.2%
D - 22 (37.3%)

TOTAL =77

Began
Training

A - 87
B - 40
C - 42
D - 37

TOTAL = 206

Withdrew
after begining
training

A - 7
B - 2
C - 2
D - 1

TOTAL = 12

Received
Training

A - 80
B - 38
C - 40
D - 36

TOTAL = 194

Variation in percentages of washouts significant at 1% level of confidence. Also significant at 1% level of confidence where A's and B's pooled, and C's and D's pooled.

Washed
Out

A - 12 (5)* (15.0%) } 16.9%
B - 8 (3)* (21.1%)
C - 12 (1)* (30.0%) } 38.2%
D - 17 (4)* (47.2%)

Total
= 49

Lincensed

A - 68
B - 30
C - 28
D - 19

TOTAL
= 145

*These values are the number of subjects who washed out before taking the private pilot's examination.

TABLE 5

CRITERION DATA

SOURCE	TYPE
FLIGHT INSPECTOR:	OVER-ALL GRADE ON FLIGHT TEST GRADES ON MANEUVERS IN FLIGHT TEST PASS-FAIL
FLIGHT EXAMINER:	OVER-ALL GRADE ON CHECK FLIGHT GRADES ON MANEUVERS IN CHECK FLIGHT OHIO STATE FLIGHT INVENTORY MEASURES
PHOTOGRAPHIC RECORDS:	ON FOLLOWING MANEUVERS IN CHECK FLIGHTS: TAKE-OFF STRAIGHT AND LEVEL 360° STEEP TURNS LANDING
FLIGHT INSTRUCTOR:	GRADES ON DAILY FLIGHT LESSONS VERTICAL ACCELERATION IN LANDINGS
TIME MEASURES:	TIME TO SOLO TOTAL TIME FOR COURSE

The findings, in so far as the pass-fail criterion is concerned are presented in Table 6 and also summarized in Exhibit A. As is apparent, the percentage of failures is 15 per cent for subjects in Group A; 21.1 per cent for subjects in Group B; 30 per cent for subjects in Group C; and 47.2 per cent for subjects in Group D. The variations in percentages between successive groups is in every case significant at the 1 per cent level of confidence. The percentage of failures in Groups C and D combined (38.2) is more than twice as high as the percentages in Groups A and B combined (16.9) and the differences in percentages between these combined groups is also significant at the 1 per cent level of confidence. In other words, the evidence convincingly supports the conclusion that a higher percentage of student pilots with defects in visual acuity will fail during flight training than will student pilots without such defects. Moreover, the probabilities of failing increase as the visual defect becomes more extreme.

The thirteen remaining measures on which the analysis has been in part completed are described in Exhibit B. In considering these, it should be noted that the weights 1, 2, 3, and 5 have been assigned to grades given by flight examiners during the first, second, third and fourth check flights, respectively. To obtain weighted scores covering grades given by instructors during dual flight, grades given for the lessons in each of four quarters were averaged, and a weighted average then computed by assigning the weights 1, 2, 3, and 5, respectively, to the four successive quarters. Underlying such weighting is the point of view that criterion measures become progressively more important as the subject approaches the point of taking the private pilot examination.

As a first step in the analysis of the thirteen criterion measures listed in Exhibit B, average scores were computed on all measures for all of the visual groups. Table 7 shows the rank order of the four groups in terms of average score on each of the 13 criteria. On all of the criteria but one (Purdue Rating Scale)

EXHIBIT B

CRITERION MEASURES

Criterion Measure	Explanation
1. Weighted Over-all Grade (Instr.)	During each dual flight the instructor assigned a grade on the basis of his judgment of the over-all performance.
2. Weighted Mean Maneuver Grade (CP)	To each maneuver performed by the subject, the check pilot assigned a grade on the basis of his judgment. These were averaged for each check flight.
3. Weighted Over-all Grade (CP)	During each check flight the check pilot assigned a grade on the basis of his judgment of the over-all performance.
4. Weighted O.S.F.I. Score (1-I/A)(CP)	During each check flight the check pilot filled out the Ohio State Flight Inventory on the basis of his observations of the subject's performance. A = the largest possible error score that the subject could have. This is actually the error score for all items that were not omitted by the check pilot. I = the subject's total error score.
5. Weighted Mean Maneuver Grade(Instr.)	During each dual flight the instructor assigned a grade to each maneuver on the basis of his judgment. These were averaged for each lesson.
6. Mean Maneuver Grade (CP) Last CF	As 2, above, but based only on the last check flight.
7. Over-all Grade (CP) Last CF	As 3, above, but based only on the last check flight.
8. O.S.F.I. Score (1-I/A)Last CF (CP)	As 4, above, but based only on the last check flight.
9. Purdue Sum (Instr.)	Sum of item scores on the Purdue Rating Scale. As scored, the higher the score, the poorer the pilot. Filled out by the instructor at the end of the training.
10. Time to Solo (logarithm)	The logarithm of the number of minutes of dual training prior to the first solo flight. It is assumed that this measure is a good index of the instructor's judgment of the pilot's competence. The logarithm is used instead of the number of minutes because of the skewness of the distribution. Using the logarithm tends to make the data more normal. The logarithm also has greater a priori

Criterion Measure	Explanation
	validity than the number itself because it gives greater wieght to small differences at the low end of the scale and less weight to small differences at the high end of the scale. If the subject was never permitted to solo, the point was arbitrarily set at forty hours, or 2400 minutes.
11. Weighted Landing Manuever Grade (CP)	As indicated under 2, above, the check pilots assigned grades to each maneuver. These are the grades on the landings.
12. Weighted Landing O.S.F.I. Score (CP)	Error score on the O.S.F.I. landing sheet. Recorded by the check pilot during the check flights.
13. Weighted Mean Maneuver Grade on Practice Landings (Instr.)	Grade based on instructor's judgment of student's performance of landings during the dual flights.

TABLE 6

NUMBER AND PERCENTAGE OF WASHOUTS IN EACH GROUP

GROUP	NUMBER TRAINED	WASHOUTS N	WASHOUTS %	
A	80	12	15%)	17%
B	38	8	21%)	
C	40	12	30%)	38%
D	36	17	47%)	

TABLE 7

RANK ORDER OF GROUP MEANS FOR VARIOUS CRITERION MEASURES

CRITERION	RANK 1	RANK 2	RANK 3	RANK 4
WTD. OVER-ALL GRADE (I)	A	B	D	C
WTD. MEAN MAN. GRADE (CP)	B	A	C	D
WTD. OVER-ALL GRADE (CP)	A	B	C	D
WTD. OSFI SCORE (CP)	A	B	C	D
WTD. MEAN MAN, GRADE (I)	A	B	C	D
MEAN MAN. GR. LAST C.F. (CP)	B	A	D	C
OVER-ALL GRADE LAST C.F. (CP)	A	B	D	C
OSFI SCORE LAST C.F. (CP)	A	B	C	D
PURDUE RATING SCALE	A	C	B	D
TIME TO SOLO (LOG)	B	A	C	D
WTD. LANDING MAN. GR. (CP)	A	B	C	D
WTD. OSFI SCORE: LANDING (CP)	A	B	C	D
WTD. MEAN MAN. GRADE: LANDING (I)	A	B	D	C

Groups A and B make better average scores than does either of the other two visual groups.

This general order of proficiency applies not alone to grades obtained by combining successive check flights but appears also, in the case of practically all criterion measures, throughout the period of training. Figures 1 to 3 inclusive, representing learning curves for various criterion measures, show quite clearly that the performance of Groups C and D is consistently inferior to that of Groups A and B at each stage of learning as represented by check flights given at the end of the 7th, 15th, 25th, and 35th hour of flight training. As will become apparent from the discussion which follows, statistically significant relationships were found between visual efficiency and flight performance in the case of the criterion measures represented in Figures 1 to 3, inclusive. However, even in the case of other measures such as time-to-solo, represented in Figure 4, in terms of which significant differences between visual groups were not evident, the tendency towards inferior performance of Groups C and D at a given time in the course is apparent.

The thirteen criterion measures listed in Exhibit B were also analyzed by the methods of analysis of avariance. In addition to the major variable visual groups, two others, classes and instructors, were considered to introduce sufficient variation in the criterion measures to make necessary their control in the statistical analysis. Ideally, the analyses should have been conducted by a three-way classification design, but the data were not such as to permit this type of analysis. The experiment was conducted over a period of six academic quarters, and there were several instances in which flight instructors resigned and were replaced between quarters. Because of this there would be many empty cells in a three-way classification design, making such an analysis impossible.

As a result, two analyses were made for each criterion measure. In the first, the variables visual groups and classes were controlled; in the second, the variables visual groups and instructors were controlled. In each analysis the sums of squares and degrees of freedom were divided into four components; visual groups, classes (or instructors), first order interaction, and residual. The residual, or within-groups variance, was used as the error term in the computation of each F.

A major limitation of such a design is that in the first type of analysis precision is reduced by the fact that the error term contains the variation due to instructors; in the second, by the fact that the error term contains the variation due to classes. However, values which prove significant have greater generality than if the error term had the variation due to both of these sources removed. Thus, for example, a significant F for the visual groups by classes analysis (F = variance due to visual groups/error variance) may permit generalization to the polulation of instructors.

In Table 8 are presented results obtained from these analyses. This shows the p-values applying to each F, as well as the average score of each visual group on each of the criterion measures.[7] From this table it may be seen that:

[7]There were several instances in which an instructor did not have students in all visual groups. Data from these instructors were not included in the visual groups by instructors analysis. However, every class had students in each visual group, although Class 2 was dropped in the Visual group-by-classes analysis in so far as the Purdue Rating Scale was concerned because of the incompleteness of data on this scale. Whereas the means based on the visual groups by classes have the advantage of being based on somewhat more cases, the means based on the visual groups by instructors do not contain any bias due to the fact that the instructors may not be equitably distributed among the visual groups.

TABLE 8

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE: P-VALUES FOR F-TESTS. MEANS OF CRITERION SCORES FOR VISUAL GROUPS

Visual Groups by Classes

Criteria:	1 Wtd. Ov-All (I)	2 Wtd. MMG (CP)	3 Wtd. Ov-All (CP)	4 Wtd. OSFI (CP)	5 Wtd. MMG (I)	6 MMG Last CF(CP)	7 Last Ov-All (CP)	8 Last OSFI (CP)	9 Purdue Sum (I)	10 TTS (log)	11 Wtd. Landing MG(CP)	12 Wtd. Landing OSFI(CP)	13 Wtd. Landing MG(I)
Analysis:													
Visual Groups	.20-.05	.05-.01	.20-.05	.20-.05	>.20	.20-.05	.20-.05	>.20	>.20	>.20	.05-.01	<.001	.20-.05
Classes	<.001	.20-.05	.20-.05	<.001	<.001	>.20	>.20	<.001	>.20	>.20	.20-.05	.20-.05	<.001
V x C	>.20	>.20	>.20	>.20	>.20	>.20	.05-.01	>.20	>.20	.05-.01	.01-.001	>.20	>.20
Means of Visual Groups*													
A	49.93 1	67.85 2	59.11 1	66.29 1	52.56 1	73.35 2	69.0 1	71.0 1	207.9 1	2.8111 2	62.77 1	14.94 1	57.26 1
B	48.86 2	67.89 1	57.85 2	65.81 2	51.02 2	73.72 1	68.2 2	70.5 2	216.8 3	2.8024 1	62.65 2	15.21 2	56.75 2
C	46.54 4	65.70 3	56.55 3	63.96 3	49.92 3	71.01 4	65.2 4	68.5 3	216.6 2	2.8260 3	59.29 3	18.23 4	53.25 4
D	47.14 3	65.31 4	54.60 4	62.35 4	49.68 4	71.90 3	65.8 3	67.4 4	244.0 4	2.8533 4	58.91 4	17.99 3	53.32 3
Analysis:	Visual Groups by Instructors												
Visual Groups	.20-.05	.05-.01	.05-.01	.05-.01	>.20	.20-.05	.20-.05	.20-.05	>.20	>.20	.01-.001	<.001	.05-.01
Instructors	<.001	>.20	.20-.05	<.001	<.001	.20-.05	.20-.05	.20-.05	>.20	.05-.01	.05-.01	.20-.05	<.001
V x I	>.20	>.20	.20-.05	.05-.01	>.20	>.20	>.20	.20-.05	>.20	.05-.01	.05-.01	.20-.05	.05-.01
Means of Visual Groups													
A	50.26 1	68.33 1	59.78 1	66.82 1	52.95 1	73.85 1	69.7 1	72.0 1	209.4 1	2.8095 2	63.42 1	14.60 1	57.88 1
B	48.85 2	67.92 2	57.98 2	65.88 2	51.10 2	73.76 2	68.5 2	70.7 2	211.1 2	2.8024 1	62.78 2	15.05 2	56.75 2
C	46.85 4	65.98 3	56.88 3	64.34 3	50.33 3	71.38 4	65.5 4	69.1 3	216.6 3	2.8260 3	59.47 3	17.89 3	54.13 3
D	47.14 3	65.31 4	54.60 4	62.35 4	49.68 4	71.90 3	65.8 3	67.4 4	244.7 4	2.8533 4	58.91 4	17.99 4	53.32 4

*Numbers underlined indicate rank order of means of visual groups in terms of proficiency of performance

1. In the visual-groups-by classes analysis, the following criterion measures show significant variation in the means at the 5% level of confidence; and of these item c shows significant variation at the .1% level of confidence:-

a. Weighted Mean Maneuver Grade (CP) -- rank order: BACD
b. Weighted Landing Maneuver Grade (CP) -- rank order: AVCD
c. Weighted Landing OSFI Score (CP) -- rank order: ABDC

2. In the visual-groups-by-instructors analysis, the following criterion measures show significant variation in the means at the 5% level of confidence; and of these items, Items d and e show significant variation at the 1% level of confidence:-

a. Weighted Mean Maneuver Grade (CP) -- rank order: ABCD
b. Weighted Over-all Grade (CP) -- rank order: ABCD
c. Weighted OSFI Score (CP) -- rank order: ABCD
d. Weighted Landing Maneuver Grade (CP) --rank order: ABCD
e. Weighted Landing OSFI Score (CP) -- rank order: ABCD
f. Weighted Landing Maneuver Grade (I) -- rank order: ABCD

In every instance, the mean score of Groups A and B are better than those of Groups C and D, although further analysis shows no significant differentiation between Groups A and B, respectively, or between Groups C and D, respectively.[8] (Table 8)

The results of the analyses so far considered show a definite relationship between visual efficiency and flight performance. However, the results cannot be interpreted as showing that all subjects with visual defects characteristic of Groups C and D failed to attain acceptable flight proficiency. Even when failers are included with passers, as is the case in all the data presented so far, there are on all 13 criterion measures subjects in Groups C and D who made scores better than the average of those attained by subjects in Group A. For example, visual groups represent a significant source of variation, at the 5% level of confidence, in performance as measured by Weighted Mean Maneuver Grade -- CP (Criterion Item 2). Nevertheless, 32% of subjects in Group C and 27% of subjects in Group D, respectively, attained scores at or above the average of subjects in Group A. (Figure 5) A similar situation is apparent in the Weighted Landing OSFI score -- CP (Criterion Item 12) where the p value proves to be well below the 1% level of confidence both in the analysis of visual groups by classes and in the analysis of visual groups by instructors. In the case of this criterion measure 32% of subjects in Group C and 22% of subjects in Group D make scores equal to or better than the average of subjects in Group A. (Figure 6)

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[8]Among other important findings presented in Table 8 are the following:

(a) Significant class variances, at the .1% level of confidence, are found in 5 of the 13 criterion measures.

(b) Significant instructor variances, at the 5% level of confidence, are found in 6 of the 13 criterion measures. Of these, 4 are significant at the .1% level of confidence.

(c) Significant visual-groups-by-classes-interaction, at the 5% level of confidence are found in 3 of the 13 criterion measures.

(d) Significant visual-groups-by instructors-interactions, significant at the 5% level of confidence, are found in 4 of the 13 criterion measures.

The analysis of the findings of the investigation is far from complete. It is therefore impossible to make a complete and final interpretation of the experimental results. Nevertheless, it does seem possible to consider further the general question of the desirability of permitting individuals with visual defects such as are represented in Groups C and D to train for the private pilot's certificate.

The situation might well be considered by reviewing a few of the facts reported in this paper. So, for example, the fact that almost 50 per cent of subjects in Group D and 30 per cent of subjects in Group C failed the private flight training course, in contrast with 15 per cent in Group A, has great practical significance. Interpreted broadly, these findings mean that a man with a defect as marked as those characterizing Group D has only 5 chances in 10 of completing a course in training for the private pilot certificate, whereas an individual with normal visual acuity has approximately 8.5 chances of completing such a training course within a period of 50 hours of flight training. When the former enrolls in and pays for a flight training course, he is making a financial investment under conditions where the probabilities for a return are much less than are those applying to the individual with normal vision. The findings on pass-fail also have practical significance in demonstrating that well-trained instructors and flight examiners do eliminate a relatively large proportion of individuals with visual defect; in other words, they find more individuals who are risks from the viewpoint of flying among visual defectives than among visual normals and they do not give them passing grades in the flight training course. Visual defectives who do not eliminate themselves by lack of interest in flight training appear to have a "good chance" to use a common phrase, of being eliminated during training.

In addition to the questions already considered, it seems important to examine the flight proficiency of subjects, with visual defects, who passed the flight examination for the private pilot's license, in comparison with the proficiency of normal subjects passing this flight test. Since, for example, there were some subjects in the D group who showed superiority to some subjects in the A group, the question remains as to whether visual ability is related to flight performance among licensed pilots, as well as among a sample of student pilots in general.

The answer to this inquiry lies in an analysis of data from only those subjects who passed the flight examination. This analysis was carried out in exactly the same fashion as were the previous analyses, except that only subjects passing the flight examination were included. As noted previously there were 68 subjects licensed in Group A, 30 in Group B, 28 in Group C and 19 in Group D. The results of this analysis indicated that, whereas in the analysis of visual groups by instructors for the entire sample significant variation was found in terms of six criterion measures, in the analysis for passers only significant variation was found on terms of only two criterion measures, namely, the weighted Ohio State Flight Inventory Score on Landing (a measure obtained from the check pilots), and the weighted Landing Maneuver Grade (a measure obtained from the instructors.) The means and p values, from the analysis of variance, are presented in Table 9. Differences in performance between Groups A and C, and A and D were most significant, as indicated by application of the t test (the visually deficient exhibiting poorer performance), whereas the differences between Groups B and C, and B and D were less significant. Groups A and B and Groups C and D did not differ significantly in terms of these measures.

TABLE 9

CRITERIA SHOWING VARIATION IN GROUP MEANS SIGNIFICANT
AT 5% LEVEL OF CONFIDENCE OR LOWER
(Total Group and "Passers" only)

CRITERION MEASURE	P VALUE: VISUAL GROUPS BY INSTRUCTORS	MEANS OF GROUPS ANAL. BY INSTRUCTOR A	B	C	D
WTD. MEAN MAN. GRADE (CP)	.05 - .01*	68.3	67.9	66.0	65.3
	.20 - .05	69.5	69.5	67.3	68.2
WTD. OVER-ALL GRADE (CP)	.05 - .01	59.8	58.0	56.9	54.6
	>20	61.1	60.8	59.0	59.1
WTD. OSFI SCORE (CP)	.05 - .01	66.8	65.9	64.3	62.4
	>20	67.5	67.8	67.7	66.8
WTD. LANDING MAN. GRADE (CP)	.01 - .001*	63.4	62.8	59.5	58.9
	.20 - .05	64.8	65.5	61.4	63.7
WTD. LANDING OSFI SCORE (CP)	.001*	14.6	15.1	17.9	18.0
	.01 - .001	13.3	13.5	16.3	15.8
WTD. LANDING MAN. GRACE ((INST)	.05 - .01	57.9	56.8	54.1	53.3
	.05 - .01	62.2	61.2	57.4	58.6

*Also significant at 5% level in analysis: Visual Groups by Classes

Underscored figures - Passers only (N = 143)
All other figures - Failers and Passers (Total group - N = 192)

It is important to note that these significant visual group variances still occur for landing measures when only subjects who were licensed were considered, and in spite of the fact that the power of the test was reduced by decreasing the size of the sample when failers were eliminated. In an effort to determine the specific aspects of landing performance in which visually deficient subjects were inferior an analysis was made of individual items on the Ohio State Flight Inventory which pertained to landing performance.

This analysis, employing chi squared, indicated that, among passing subjects only, significant differences (at or below the 5% level of confidence) existed in terms of:

a. Whether the subject did or did not stall the airplaine in landing.
b. Whether the subject did or did not correct for drift.
c. Whether the height above ground at stall was correct or incorrect.
d. Whether the landing was rated, by the check pilot, as generally "satisfactory" or "unsatisfactory."

In terms of these measures, performance of subjects in Groups A and B was superior to that of C and D subjects. (With reference to the entire group of subjects, including both passers and failers, significant differences also appeared in terms of the following aspects of landing performance, as indicated by the Ohio State Flight Inventory: Constancy direction of roll on ground; stability of wing level during roll; proper height above ground at level off.)

The results of these analyses do not indicate that all visually handicapped pilots are inferior to pilots with so-called "normal" vision, as has been indicat-

ed previsouly. However, the results do indicate that even among pilots passing the flight examination, visually handicapped pilots are somewhat less proficient in executing landings than are pilots with "normal" vision. One recomendation growing out of this study would seem to be that visually deficient pilots be required to pass a rather rigorous test in landings, and also that research be done in developing training procedures by means of which visually deficient pilots can be taught to employ to the fullest extent the cues which are available to them in spite of their visual handicap. It should be noted in passing that none of the members of Group D failed in the medical flight test given under current CAA administrative policy to all applicants having the degree of visual defect represented by this group. Of additional interest is the fact that there were no accidents in any of the four visual groups during flight training which totaled over 8,000 hours for the entire experimental program.

It may well be that the issue concerning flight training for student pilots with visual defects of the types represented in Groups C and D cannot be settled without a follow-up to determine the flight performance of the subjects in each of the groups over a period of years subsequent to licensing. Such a follow-up study has been undertaken by the Committee on Aviation Psychology. The results so far show, for example, a higher percentage of licensed pilots in Groups C and D as not having had flight experience subsequent to licensing than is found in Groups A and B; i.e. 52% and 28%, respectively. These figures are given merely to illustrate the nature of the data which are being obtained in the follow-up study which will provide information on accidents, reasons for failure to fly, as well as facts on hours of flight experience. It may be that many of the questions concerning the visual groups, particularly those regarding safety, will not be answered until some years have elapsed. It is hoped that these findings, as well as the results of additional analyses of data collected during the Visual Study investigation, can be brought to the attention of this group at a later date.[9]

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[9] It should also be noted that before final publication of the report a number of additional supplementary analyses will be added, including the correlation of selection tests with the pass-fail criterion, and determination of significance of differences, in terms of these tests, between passers and failers.

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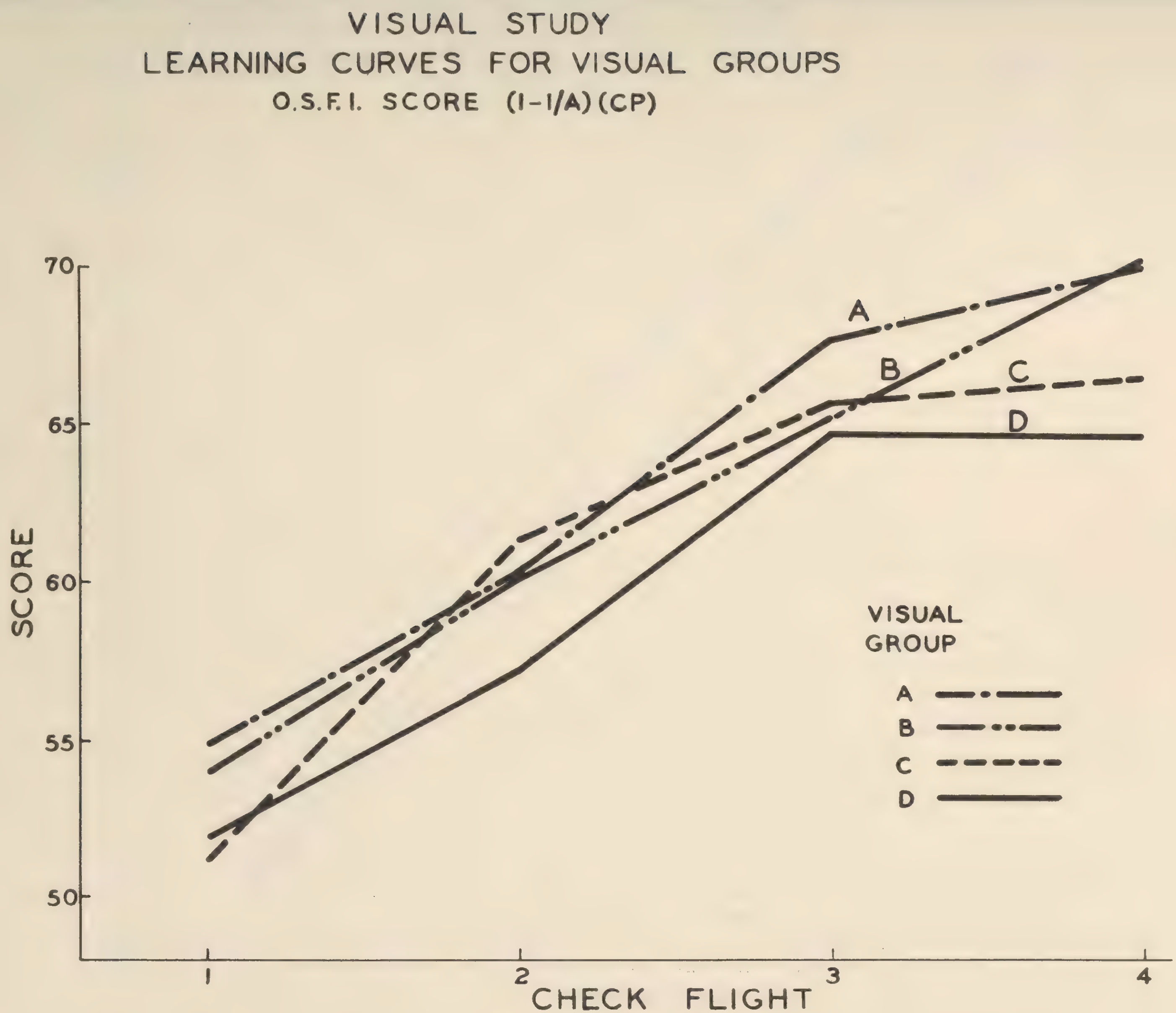
VISUAL STUDY
LEARNING CURVES FOR VISUAL GROUPS
O.S.F.I. SCORE (I-I/A)(CP)
SCORE
70
65
60
55
50
1
2
3
4
CHECK FLIGHT
A
B
C
D
VISUAL GROUP
A
B
C
D

Figure 1

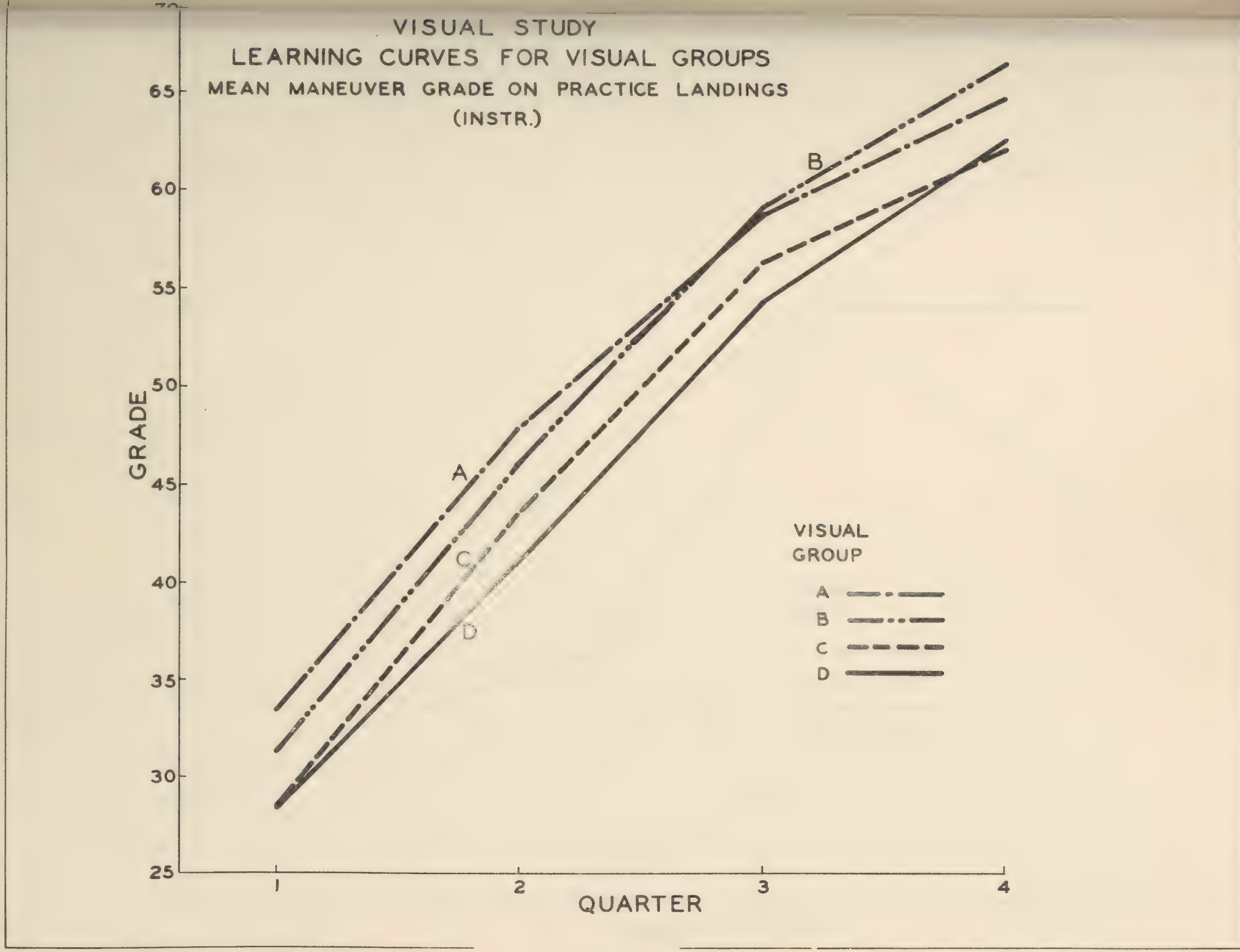
VISUAL STUDY
LEARNING CURVES FOR VISUAL GROUPS
MEAN MANEUVER GRADE ON PRACTICE LANDINGS
(INSTR.)
GRADE
65
60
55
50
45
40
35
30
25
QUARTER
1
2
3
4
A
B
C
D
VISUAL
GROUP
A
B
C
D

Figure 2

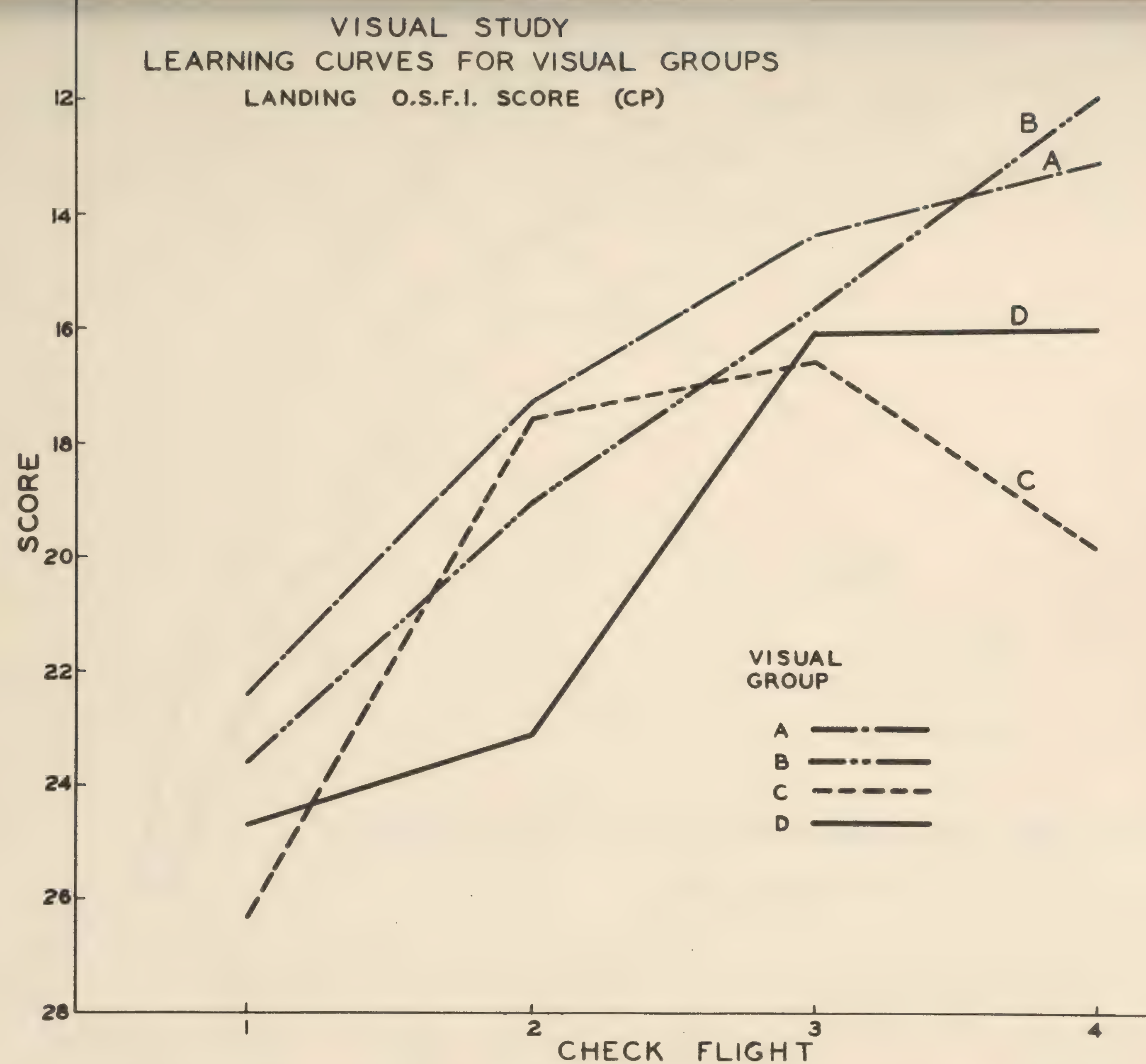
VISUAL STUDY
LEARNING CURVES FOR VISUAL GROUPS
LANDING O.S.F.I. SCORE (CP)
SCORE
12
14
16
18
20
22
24
26
28
CHECK FLIGHT
1
2
3
4
A
B
C
D
VISUAL GROUP
A
B
C
D

Figure 3

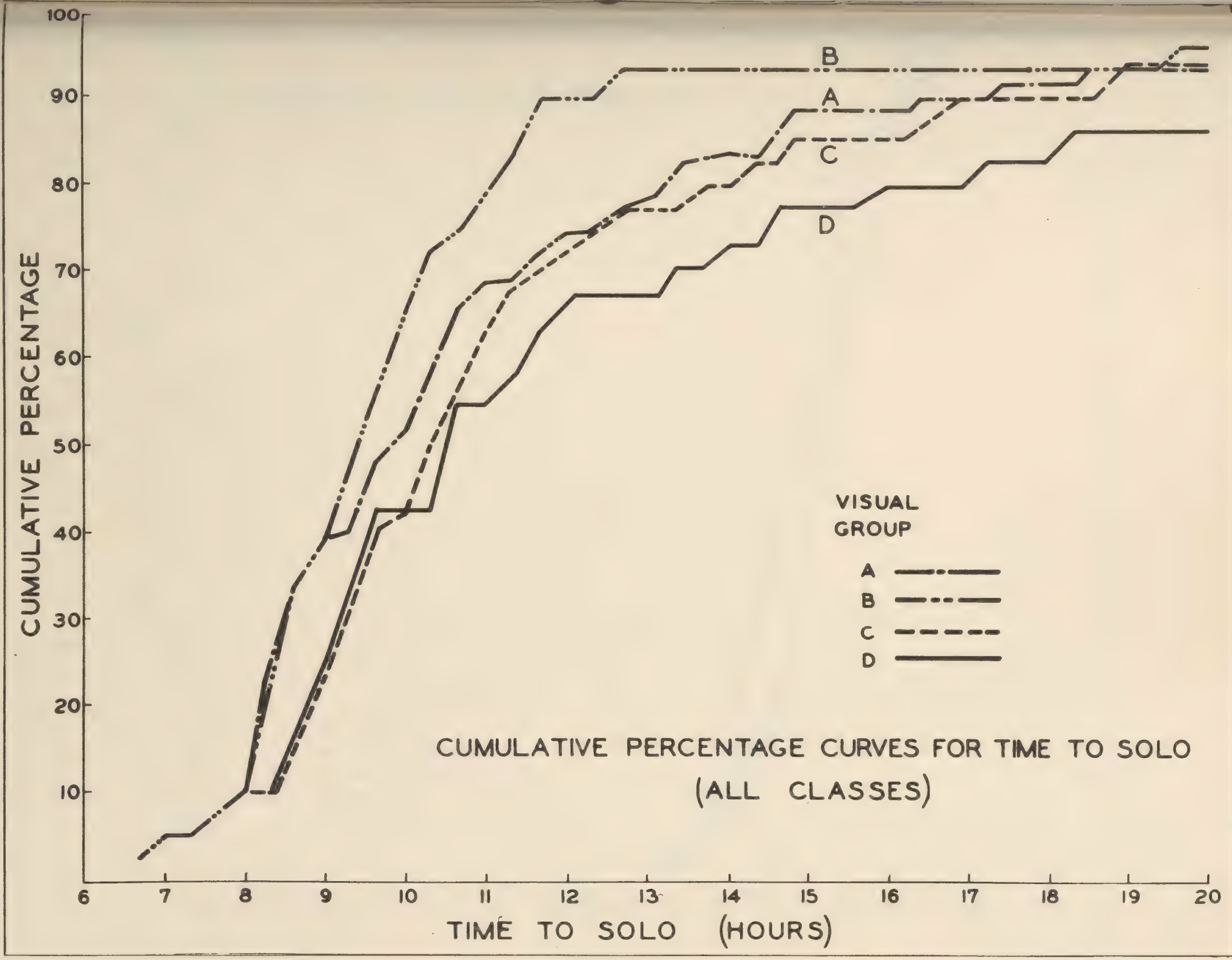
CUMULATIVE PERCENTAGE
100
90
80
70
60
50
40
30
20
10
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
TIME TO SOLO (HOURS)
B
A
C
D
VISUAL
GROUP
A
B
C
D
CUMULATIVE PERCENTAGE CURVES FOR TIME TO SOLO
(ALL CLASSES)

FIGURE 4

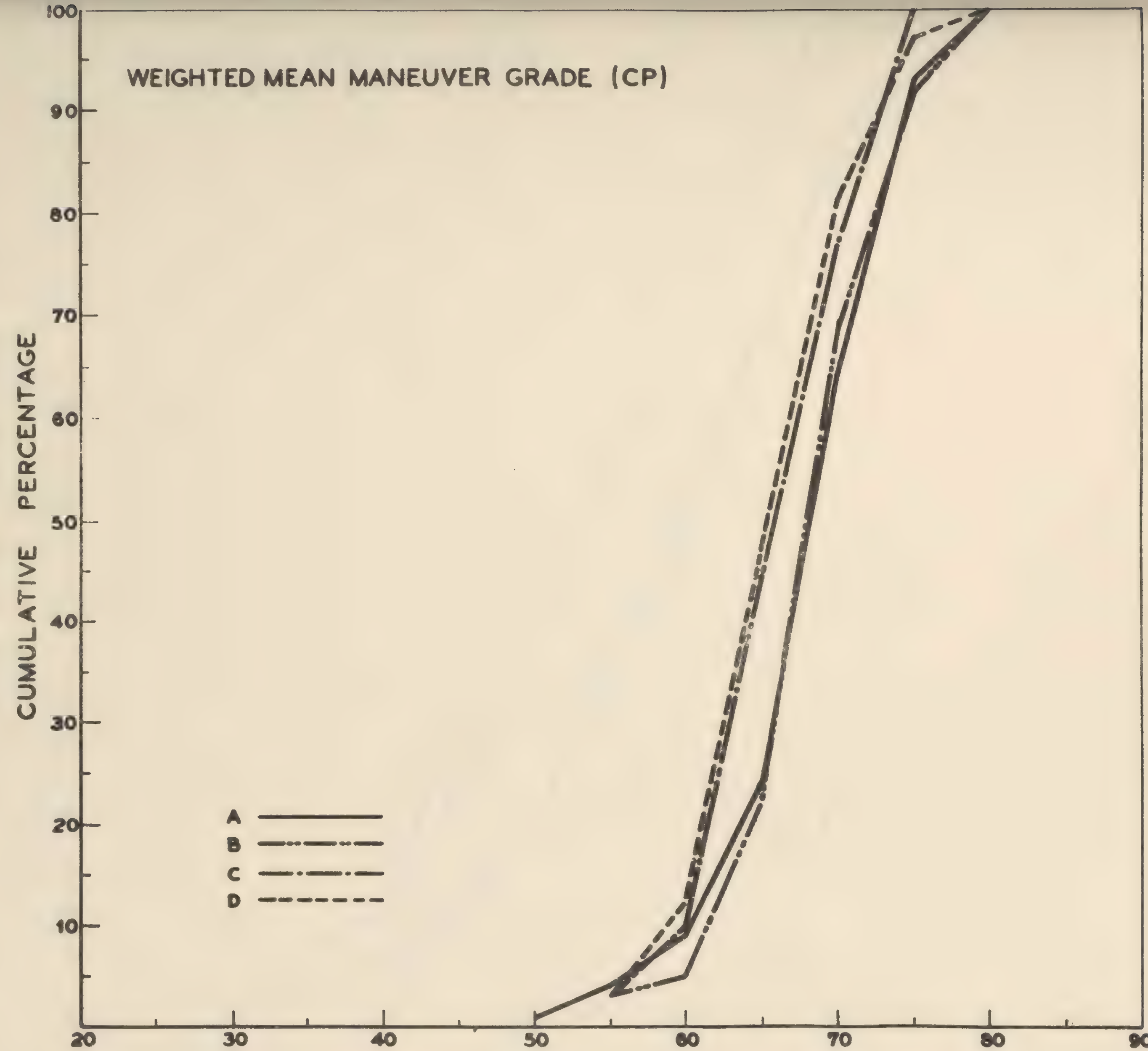
WEIGHTED MEAN MANEUVER GRADE (CP)
CUMULATIVE PERCENTAGE
100
90
80
70
60
50
40
30
20
10
20
30
40
50
60
70
80
90
A
B
C
D

FIGURE 5

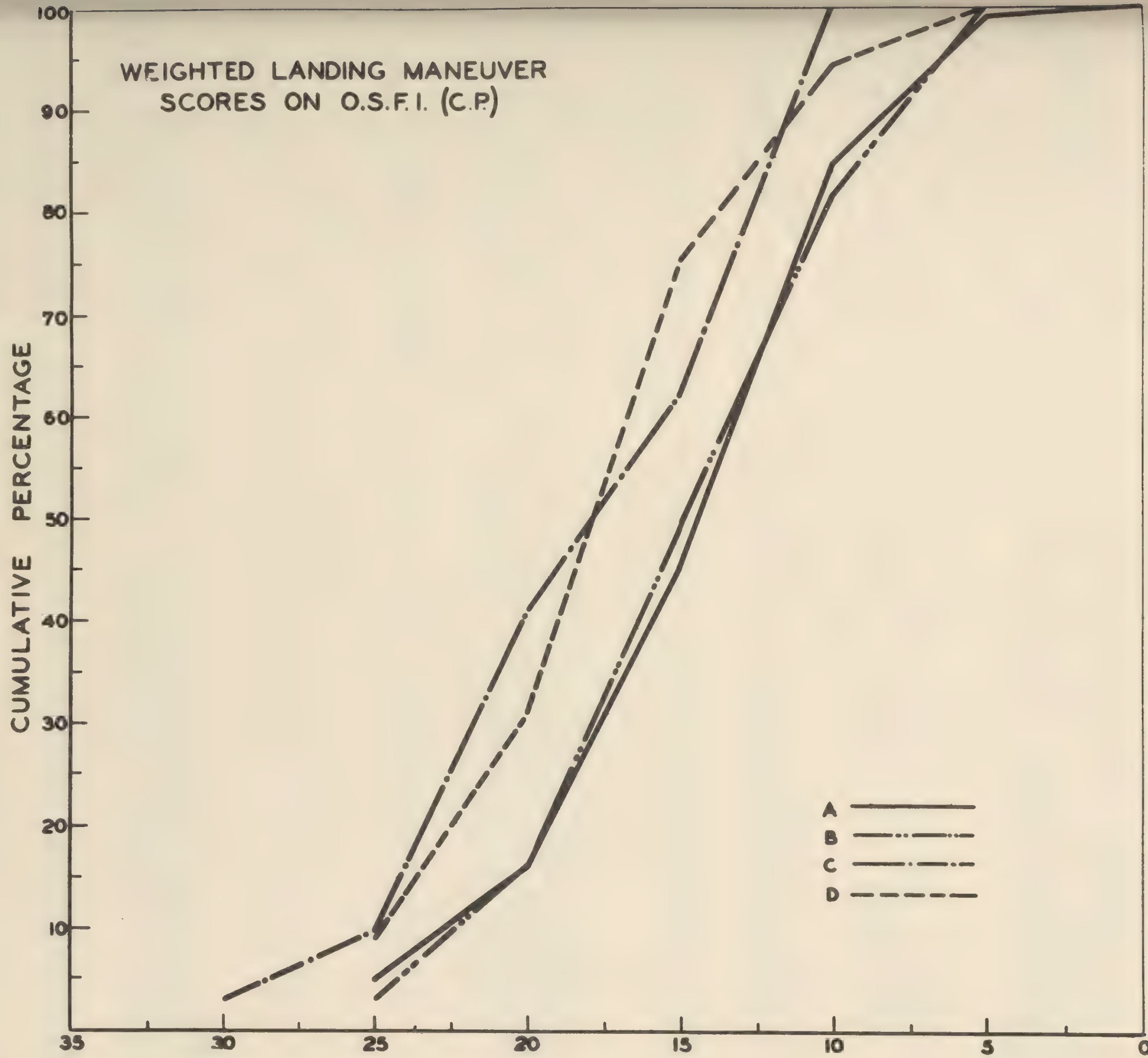
WEIGHTED LANDING MANEUVER
SCORES ON O.S.F.I. (C.P.)
CUMULATIVE PERCENTAGE
100
90
80
70
60
50
40
30
20
10
35
30
25
20
15
10
5
0
A
B
C
D

FIGURE 6

DISCUSSION:

Dr. Seitz remarked that the learning curves obtained did not become asymptotic. He raised the question whether if all learning curves were continued to the asymptote they might not come together, thus eliminating the differences in the performance between the various visual groups. He implied that perhaps the difference between the visual groups was one of the length of time required to learn to fly rather than one of final flying performance.

Dr. Viteles replied that training actually continued beyond the 35th hour of training shown on the learning curve graphs so that in effect, each flier received sufficient time for optimal performance. The results obtained indicated that not only did it take longer for the visually defective groups to learn to fly, but that in addition these groups did not ever achieve the same level of performance as the normal vision group.

Dr. MacMillan asked what precautions were taken to minimize the effect of the bias of the instructors in favor of the normal vision group. He mentioned the common impression that instructors might be expected to have, namely, that the "one-eyed" candidates could not learn to fly.

Dr. Viteles answered that the instructors utilized had been accustomed to research projects for a period of years, and that every attempt was made to eliminate the possibility of instructor bias.

Dr. Miles remarked that the men with defective vision (C and D groups) did not appear for flight training as often as the normals, and did not use their license as much even though they received it.

Dr. Viteles remarked that the reluctance of the defective vision group to fly came as a surprise to them since they had received the impression that defective vision men were extremely anxious to fly and that only CAA standards were preventing them from doing so. Apparently the individuals with defective vision who were extremely anxious to fly were not representative of the group as a whole.

Dr. Imus questioned Dr. Viteles as to the constitution of Groups B & C. He asked whether both groups wore glasses.

Dr. Viteles replied in the affirmative.

Dr. Imus then questioned whether members of Group C were corrected to 20/20 or 20/50.

Dr. Viteles replied that in Group C, a higher percentage was corrected to 20/30 than anticipated, estimating that at least half of the group were corrected in this way. Group C was a mixed group, with individuals corrected to 20/30 and other individuals corrected no better than 20/50.

Dr. Marquis asked what characteristics distinguished the members of Groups C and D who passed from those who failed.

Dr. Viteles answered that it was impossible to distinguish those who passed from those who would fail on the basis of psychological tests measuring non-visual factors. He stated further that the project is still analyzing the visual characteristics to ascertain whether visual factors were responsible for the distinction between passers and non-passers.

Lt. Comdr. Farnsworth asked whether tests on manual dexterity were included in the non-visual tests, and Dr. Viteles answered in the affirmative.

Commander Biels asked whether the classification battery used in the Navy to select aviators had been used.

Dr. Viteles answered in the negative, although he indicated that many of the tests in the Navy battery had been included, but that the exact weighting of the items in the battery was not used.

Dr. Seitz asked whether the Ohio State data could be used, together with known variation in acuity as a function of age, to predict the number of years of effective flying a pilot might have.

Dr. Viteles replied that perhaps such a step could be taken provided someone could furnish the data relating visual acuity to age.

Dr. Marquis asked if Dr. Viteles could estimate the cost in terms of man hours and money of the entire Ohio State program. He raised the question because it is generally conceded that a job analysis of all military tasks should be done to provide adequate classification of manpower in time of emergency. He felt that some estimate of the total cost of such a program could be gotten from the cost figures of the Ohio State program.

Dr. Viteles replied that the total cost of the program was probably around $100,000, of which $30,000 to $40,000 of services were supplied by Ohio State.

Captain Shilling inquired concerning the type of medical examination given candidates in order to qualify for flight training under CAA regulations.

Dr. Wigodsky reported that any licensed physician was qualified to give the examination. He reported instances in which veterinarians had been called upon to administer the medical examinations.

Dr. Viteles agreed with Dr. Wigodsky that irregularities in the medical examination undoubtedly existed. He emphasized, however, that a statistical study should be made of the validity of medical examinations in the general manner of the Ohio State study.

THE ARMY VISUAL ACUITY RESEARCH PROGRAM

by
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The purpose of this paper is to give a summary of the findings on visual research reported in PRS Report No. 742, 'Studies in Visual Acuity, Report of Progress', which many of you have already seen.

Basic material consists of two sets of data. The Army tested the left eye only of 792 enlisted men at Fort Dix, New Jersey, on a battery of 14 wall charts including letter tests, checkerboard acuity tests, line and dot acuity tests, a vernier acuity test, a modified Landolt ring acuity test, dot and chevron brightness discrimination tests, and triangle and square difficult form (edge) discrimination tests. The Navy tested left eye, right eye, and binocular vision of 128 individuals at the New London Submarine Base in Connecticut using near and far letter acuity wall charts and far acuity, near acuity, depth, and phoria (the last two for both eyes only) tests as contained in the Bausch and Lomb Orthorater, the American Optical Company Sight-screener, and the Keystone Telebinocular.

Treatment consisted of factorial analysis of all data and, in addition of item analysis (for difficulty) for the Army Data. The accompanying tables bring together all information concerning a given test from the two sources and from all analyses. This is done with the hope that the easy comparison from test to test will make easier the selection of the best test in each area.

Since the tables make constant reference to factor loadings, it will be well to describe the factors found, briefly. There were 12 common factors, i.e., factors of importance to two or more tests, disregarding factors specific only to test-retest or test-alternate test groups. These, along with a brief description for each, were:

1. Retinal Resolution: This is the basic visual acuity factor based upon the resolving power of the retina.

2. Accommodation: This factor is present in all near acuity and near depth tests. It is based upon the accommodating power of the lens.

3. Form (Letter) Perception: This factor is present in all letter tests in other tests requiring the identification of simple, well known, easy form discriminations.

   Note: In both factor 2 and 3 the right eye was dominant with respect to the factor, with a hierarchy of habits such that accommodation tended to somewhat suppress letter perception when both were required.

4. Form (Edge) Perception: This factor was present in the triangle and square edge discrimination tests only. It is poorly defined in the present battery.

5. Brightness Discrimination: This factor was highest in the dot and chevron contrast tests, but also present in other far acuity tests where focussing was not essential to the correct response.

6. Resistance to Interference: This factor tends to be present for all present machine charts. Elements known to be detrimental to visual perception and present in one or more of the charts with high loadings on this factor include: (a) inhibitory effects of large black areas on the visual field, (b) disturbance due to sharp or marked boundaries surrounding the stimuli; (c) reduced apparent brightness due to fusion of dark area from the non-tested field of vision, (d) rivalry due to different fields for the two eyes, and (e) distraction due to effect of brighter areas near the stimuli. Factor loadings tended to be higher when the left eye was being tested, i.e, when the disturbing factors were presented to the dominant eye.

7. Depth perception: This factor was common to all the present machine test charts, where displacement of left or right eye image was the only cue remaining.

8. Lateral Phoria: This factor was present on all lateral phoria tests, far and near, machine chart and Maddox Rod.

9. Near Lateral Phoria (Convergence Efficiency): This factor was present for near but not for far lateral phoria tests, but for both machine charts and Maddox Rod.

10. Vertical Phoria: This factor was present for all vertical phoria tests, near and far, machine chart and Maddox Rod. (There was no separate near vertical phoria factor.)

11. Anti-Fusion Factor: This factor is present in all Maddox Rod measurements, vertical phoria Sightscreener measurements, and in special far excursion measurements on the Orthorater. It is named after the effort made in these measurements to prevent the full action of the fusion center, either by interrupted vision or by asking reports on the greatest excursion noted.

12. Vertical Phoria Rest: This factor was present for test but not for retest on the Orthorater, Sightscreener, and Telebinocular vertical phoria tests. It suggests that vertical phoria measurements are especially subject to fatigue effects.

In general the factors are completely independent of one another. Very slight relationships (not accounting for over 3% overlap) were found for Accommodation and Lateral Phoria and between Vertical Phoria and Depth Perception. In general it was concluded, however, that any thorough study of the role of visual factors in military or other occupational success would have to take account independently of all of the first eleven factors listed above. Factor 12 would indicate the necessity of controlling fatigue in any such study.

We will turn now to the tables. There, tests supposedly measuring the same function have been grouped together. For each test in each group the name, reliability data, factor loadings for the supposedly pertinent function, non-pertinent factor loadings, and item-analysis findings are given in so far as the information is available. Reliability coefficients were not available for the Maddox Rod in Tables G, H, and I. Item-analysis information was not available for groups E through I.

Group A consists of Letter tests for Far Acuity. The first three tests are the Snellen, New London, and AAF line decrement wall charts. They all have about equal reliability, equal loadings on resolution, and about equal score contamination due to the letter factor. The first line and middle column of the remaining factor

loadings are for the left eye. Note that here the resolution loadings are higher while the letter loadings are lower, indicating the dominance of the right eye for letter perception. The item analysis indicates that all tests are badly scaled, despite the work done in this direction by the Navy and the AAF. The fourth test, the AAF, Letter constant decrement test, shows almost identical coefficients and equally bad reversals in the scaling. It would appear that letter tests cannot be made into accurate measurement instruments. The two remaining tests were machine line decrement charts, for which item analyses were not available. The Sightscreener chart shows loadings quite similar to those for the wall charts, except that impurity, while of about the same magnitude, is now distributed over both letter perception and resistance to interference. The Telebinocular test is definitely inferior to the other tests in all respects. Most serious defect is in plate construction resulting, due to absence of focusing cues, in negative loadings on the accommodation factor.

Group B consists of non-letter charts for far acuity. Despite the absence of adequate range at the easy end of the scale, which perhaps accounts for its slightly lower reliability, the Checkerboard wall charts are definitely superior to all other far acuity tests in either group. The resolution loadings are highest, non-pertinent loadings are absent, scaling is excellent and overlap of difficulty from line to line is absent. When used in the Orthorater, the reliability increases, loadings on resolution are reduced to the level of those for letter charts in the last group, non-pertinent loadings due to interference replace and are about equal to those due to the letter factor in the letter charts, while item analysis is not available. The lower resolution loadings and the higher resistance to interference loadings indicate that the left eye readings are more influenced by interference introduced by the machine charts. The next two tests, line and dot resolution wall charts, have reliability, resolution loadings, and impurity loadings of about the same magnitude as those for the letter charts in Group A. The non-pertinent loadings are due to brightness discrimination, apparently due to the ability to substitute brightness difference for resolution in locating the stimuli. Item analysis shows that both tests can be adequately scaled. The remaining two tests, Landolt square and Vernier discrimination, have satisfactory reliability, slightly lower resolution loadings, double impurity factors-being contaminated by both brightness and letter factors, and show relatively good scaling.

To summarize the findings for these two groups, we conclude that: (1) The checkerboard wall chart is the best test available, and shows the best promise for improvement, (2) Any non-letter test can be made into a true measuring device while the prospects for doing this with letter charts seems hopeless, (3) the present resistance factor on machine charts is no greater than are the brightness or letter factors present on all wall charts except the checkerboard type, and so machines could be substituted for present wall charts with little loss.

Group C consists of two brightness contrast wall charts, dot and quadrant. Both were quite unreliable, and both were better measures of resolution than they were of brightness. Both were satisfactorily scaled but too hard. An experiment is under way to see how satisfactorily these brightness loadings can be increased by partialing out the resolution loadings. In this same connection a study is being made to compare the possibility of using the dot variable size and line resolution tests as brightness discrimination tests by the same partialing procedure. If this latter method should prove successful it would eliminate the tremendous cost of producing brightness discrimination tests. Present methods of measuring this factor are not satisfactory and are too expensive as well.

Group D consists of two attempts to measure hard form (edge) discrimination by requiring judgement as to which of four triangles had a curved side or which of several squares had curved sides. Neither test was reliable, and neither had very high loadings on the Form (Edge) Factor. Impurities consisted of resolution and brightness for both tests. An experiment is planned to test the relationship of ordinary paper-and-pencil spatial tests to both the Form (Edge) and the Form (Letter) factors.

Group E consists of near acuity tests. No test is outstanding in this group. All show moderate reliability, and about equally moderate loadings on both accommodations and resolution. Letter tests show letter contamination while machine tests show about equal interference contamination. Most striking finding is the important role of resolution (far acuity) in these readings. Only if the resolution factor is controlled will the near acuity readings give an independent measure of accommodation. The present mixed scores cannot be interpreted due to their mixed nature.

Group F consists of the three machine depth tests. Orthorater and Telebinocular show moderate reliability with the Sightscreener lagging behind. All tests show relatively high contamination with the resolution factor. The telebinocular test shows two additional types of contamination-letter and interference. Due to the lower reliability of the Sightscreener and the greater contamination of the Telebinocular, the Orthorater shows the highest Depth loadings. The Orthorater and Sightscreener if made more reliable and if resolution could be partialled out, might prove to be satisfactory measures of the depth perception factor.

Group G consists of near and far machine and Maddox Rod vertical phoria tests. Reliabilities are about equal and fairly low. Near and Far tests have quite similar loadings on the Vertical phoria factor, except that the near Maddox Rod measurement is especially low. Contamination is of two kinds: (1) the sightscreener and Maddox Rod show loadings on the Anti-Fusion factor, while the test, as opposed to retest scores, for the Orthorater Far, Sightscreener Far, and Telebinocular Far tests show a special Rest factor for these vertical phoria measurements. No test in the group is very satisfactory.

Group H contains only the Lateral Phoria Far tests. The Orthorater test seems to be outstanding in reliability and highness of the far lateral loadings, while the Maddox Rod appears to be the poorest measuring device, containing a non-pertinent Anti-fusion element similar to that introduced into the Orthorater by asking for special reports of the furthest excursion noted rather than waiting until the images came to rest.

Group I contains the near later phoria tests. All are reliable. All show a high contamination due to Far Lateral Phoria loadings, and all have moderate loadings on the special near lateral factor, with the Orthorater and Telebinocular showing a slight edge over the Sightscreener. The near measurement via the Maddox Rod holds up for lateral measurements rather than falling off as did the near vertical measurements, although again it does show contamination by the Anti-Fusion factor.

To summarize findings for groups E through I, it is concluded that: (1) Tests for near acuity and depth must be corrected for resolution before they can be interpreted as Accommodation and Depth Perception measurements per se, and both show only moderate reliability at present, (2) The Orthorater has the best present depth test, (3) All present near vision tests show added contamination due either to letter or interference contamination. This could probably be overcome by adopting a checkerboard wall chart for this measurement, (4) Vertical Phoria tests are all quite unre-

liable, with the Orthorater far test showing a slight edge over the field and the Maddox Rod coming in a bad last, (5) On the other hand, lateral phoria tests, both near and far are quite reliable, (6) The Orthorater and Telebinocular tests are best in the near lateral field, but would have to be corrected for far lateral contamination, while the Orthorater holds a slight edge over other measures in the far lateral field.

A. Letter Tests, Far Acuity

Test	Reliability	Resolution Loadings	Non-Pertinent Loadings	Item-Analysis Findings
Snellen	.88, .83, .77 .81	.85, .85, .90 .70, .86, .77 .78, .84, .77	Lt: .24, .26, .32 .41, .26, .50 .28, .24, .42	High variability and overlap. Level is O.K.
New London	.88, .89, .87 .83	.84, .85, .89 .79, .83, .81 .80, .83, .81	Lt: .21, .39, .25 .41, .34, .37 .42, .31, .41	High variability and overlap. Hard.
A.A.F. (reg.)	.89	.89, .90, .89	Lt: .29, .28, .32	High variability and some overlap. Hard.
A.A.F. (C.D.)	.87	.87, .87, .89	Lt: .24, .25, .29	Bad reversals. Hard.
Sight Screener	.88, .81, .73	.75, .86, .81 .80, .90, .82	Lt: .26 Rt: .18, .15	No data.
Telebinocular	.86, .78	.65, .72, .62 .63	Ac: -.15, -.15 -.24, -125 Rt: .18, .23	No data.

B. Non-Letter Tests, Far Acuity

Test	Reliability	Resolution Loadings	Non-Pertinent Loadings	Item-Analysis Findings
Checkerboard (Wall chart)	.79, .81	.90, .93, .90 .90, .89, .90		Excellent, no overlap. Hard.
Checkerboard (Orthorater)	.86, .87, .83 .76, .88, .87	.86, .77, .86 .85, .78, .83 .85, .79, .80 .82, .77, .79	Rt: .42, .44, .23 .44, .52, .50 .40, .48, .20 .35, .49, .37	No data
Dot Variable Size	.85	.87, .90, .90	Br: .31, .22, .20	Excellent, no overlap. Hard.
Line Resolution	.85	.82, .85, .88	Br: .44, .31, .31	Excellent, no overlap. Easy.
Landolt Square	.80	.80, .79, .82	Br: .21, .29, .21 Lt: .18, .20, .18	Some variability no overlap. Easy.
Vernier	.80	.72, .73, .80	Br: .29, .27, .32 Lt: .17, .24	Excellent, little overlap. Easy.

C. Brightness Contrast Tests

Test	Reliability	Brightness Loadings	Non-Pertinent Loadings	Item-Analysis Findings
Dot Contrast	.43	.41, .20, .40	Rl: .54, .64, .59	Regular. Hard.
Quadrant Contrast	.57	.55, .48, .37	Rl: .55, .58, .65	Regular. Hard.
See also: Dot variable size and Line resolution in Section B, above.				

D. Form (Edge) Tests

Test	Reliability	Form(Edge) Loadings	Non-Pertinent Loadings	Item-Analysis Findings
Triangle	.69	.29, .42, .32	Rl: .63, .66, .68 Br: .28, .16, .19	Irregular. Easy.
Square	.44	.46, .45, .32	Rl: .40, .34, .35 Br: .19, .17 Lt: .21	Slightly irregular. Easy.

Abbreviations: Ac.=accommodation; Br.=brightness; Lt.=letter; Rl=Resolution; Rt.=Resistance to interference.

E. Near Acuity Tests

Test	Reliability	Accommodation Loadings	Non-Pertinent Loadings
New London, Letter, Wall	.73, .78, .67	.48, .42, .51 .50, .43, .58	Rl: .53, .54, .54, .57, .61, .52 Lt: .19, .31, .28, .31, .40, .23
Sightscreener, Letter	.73, .81, .70	.49, .42, .51 .50, .39, .53	Rl: .64, .61, .59, .63, .69, .62 Lt: .17, .17 Rt: .23, .20, .22
Telebinocular Letter	.65	.47, .37	Rl: .41, .43 Lt: .19, .26 Dp: .18, .11
Orthorater, Checkerboard	.85, .82, .85 .78, .84, .79	.66, .48, .59 .59, .56, .62 .70, .47, .57 .60, .49, .57	Rl: .56, .69, .63, .58, .70, .59 .55, .66, .61, .54, .69, .62 Rt: .38, .31, .29, .33, .25, .35 .20, .24, .16, .37, .29, .24
Telebinocular Circles	.71, .72, .72	.50, .39, .44 .43, .42, .40	Rl: .53, .49, .47, .52, .56, .38 Lt: .18, .17 Rt: .19, .26, .17, .21

F. Depth Tests

Test	Reliability	Depth Loadings	Non-Pertinent Loadings
Orthorater	.75, .72	.61, .69, .66 .64	Rl: .49, .52, .44, .48
Sightscreener	.57	.43, .44	Rl: .42, .40
Telebinocular	.79	.32, .35	Rl: .41, .49 Lt: -.13, -.17 Rt: .30, .21

G. Vertical Phoria Tests

Test	Reliability	Vertical Loadings	Non-Pertinent Loadings
Orthorater, Far	.55, .61	.67, .50, .73 .67, .71	VR: .44
Orthorater, Near	.63, .55	.49, .59, .59 .54, .73	
Sightscreener Far	.61	.40, .57	AF: .48, .78 VR: .20
Sightscreener Near	.55	.54, .47	AF: .57, .62
Telebinocular Far	.63	.41, .49	VR: .46
Maddox Rod, Far		.43	AF: -.27
Maddox Rod, Near		.20	AF: -.33

Abbreviations: AF.=anti-fusion; Dp.=depth; Lt.=letter; Rl.=resolution; Rt.=resistance to interference; VR.=vertical phoria rest.

H. Lateral Phoria Tests, Far

Test	Reliability	Far Lateral Loadings	Non-Pertinent Loadings
Orthorater, Regular	.88, .74	.92, .81, .82 .88, .81	
Orthorater, Excursion	.84	.86, .77	AF: .30, -.36
Sightscreener	.74	.71, .75	
Telebinocular	.75	.71, .77	
Maddox Rod		.60	AF: .39

I. Lateral Phoria Tests, Near

Test	Reliability	Near Lateral Loadings	Non-Pertinent Loadings
Orthorater, Regular	.92, .76	.68, .52, .62 .67, .65	FL: .61, .70, .68, .32, .24
Orthorater, Excursion	.86	.65, .78	FL: .50, .33 AF: -.26, -.28
Sightscreener	.83	.47, .49	FL: .69, .66
Telebinocular	.85	.70, .57	FL: .42, .54
Maddox Rod		.58	FL: .53 AF: .41

Abbreviations: AF.-anti-fusion; FL.=far lateral phoria.

Note: All data reported in these tables were taken from:

Studies in Visual Acuity
Report of Progress
PRS Report No. 742

by

The Adjutant General's Office
Personnel Research and Procedures Branch
Personnel Research Section
Washington, D. C.

DISCUSSION:

Dr. Imus rose to compliment Dr. Wherry upon his clear presentation of a very difficult subject matter.

Colonel Lowrey asked if the Committee intended to recommend the checkerboard test for general use as a result of the AGO study. He mentioned the difficulties that would be involved in obtaining such materials, and mentioned also his belief that the single checkboard test would not be appropriate as a general vision test since it measured only the one factor named resolution.

Dr. Wherry commented that it was the intention of the AGO study to isolate the factors in vision and to develop reliable and pure tests for each. However, before attempting any test for any selection purpose, a job analysis would be required, following which a test could be developed incorporating tests of the various factors in appropriate proportions.

Dr. Rand asked whether the checkerboard test results were not influenced by astigmatism.

Dr. Wherry reported that he believed all tests were influenced by astigmatism.

Dr. Sloan suggested that the checkerboard test was indeed influenced less than it should have been by astigmatism.

Dr. Wherry reported that an inadequate measure of astigmatism was used. The ordinary line astigmatism test which was used did not yield reliable results. Accordingly, no conclusion could be made concerning the effect of astigmatism on various of the tests used.

Dr. Graham asked whether the tests had been given the scotopic as well as photopic illuminations.

Dr. Wherry reported that only photopic illuminations had been used, in accordance with specifications of the Vision Committee manual for testing visual acuity.

Dr. Dimmick reported that checkerboard test was being investigated at scotopic levels at the Medical Research Laboratory of the Submarine Base. He reported that before testing could begin on the checkerboard charts, each chart had to be investigated to be certain that there was equivalence within each figure of the chart. He reported that experimentation with the charts might well begin within a month.

Colonel Lowrey asked what the difference in visual acuity measurements would be between the tests having the highest and those having the lowest factor loadings.

Dr. Wherry replied that he assumed Colonel Lowrey was referring to the factor loadings on resolution of the various tests. He pointed out that the factor loadings on resolution were not very different for the various tests of far acuity. An important point he made, however, was that only the checkerboard test was free from extraneous factor loadings. Used alone,therefore, the checkerboard test could become almost a pure measure of the factor called resolution, of increasing reliability as the number of items in the test was increased.

Dr. Kennedy asked what the so-called instrument interference factors were thought to be.

Dr. Wherry replied that it was impossible to pin down a single cause of "instrument interference." He mentioned several possible causes such as the presence of sharp contrast borders, the presence of large black surfaces in one eye and not in the other, and the presence of large white surfaces which were distracting to certain individuals. One or more of these effects was present in each of the machine tests.

Dr. Rand asked whether illumination was constant on all the tests compared. She asked further whether the exact value used on the wall charts was known. Dr. Rand implied that perhaps differences in illumination in the various machine tests was responsible for the decrement in acuity explained by the factor called instrument interference.

Dr. Wherry answered that the illumination was constant on the wall charts used by the Army, standardized at 12 footcandles. There was a variation from 8 to 14 footcandles from the bottom to the top of the chart. Variation from booth to booth and from day to day in the various booths is recorded, but is not thought to be significant. Illumination data on the machines is not available and perhaps a portion of the so-called instrument interference factor can be traced to lower illuminations than standard.

Dr. Kennedy asked whether the factor called instrument interference might not be a measure of psychic accommodation. He defined this effect as the accommodation induced in the subject because of his knowledge that the object seen in the instrument is not truly at infinity as it is made to seem optically.

Dr. Wherry replied that if Dr. Kennedy's hypothesis were correct, then negative loadings on accommodation should have been obtained in all instruments such as those that were obtained in the telebinocular.

Dr. Sulzman arose to comment that the work of the AGO was a work "beyond price". He felt that the staff had done a fine job and that the results obtained were of inestimable value to the clinical ophthalmologist.

Lt. Comdr. Farnsworth made the important point that the wall charts in the AGO study were far from standard wall chart installations. In effect, the wall charts were a part of 20-foot machines, carefully standardized as to illumination, pattern of brightness in the visual field, and method of presentation. He emphasized that unless this point were made clear, the dangerous conclusion might be drawn from the data that any wall chart administered in any fashion was a better measure of visual acuity than the machine tests.

Dr. Sulzman agreed whole-heartedly with Lt. Comdr. Farnsworth, and quipped that "any resemblence between the wall charts here and the wall charts of the ophthalmologist was purely coincidental".

Dr. Hartline commented upon the names of the factors defined by the factor analysis of the AGO results. He made the important point that assigning names to the factors might be dangerous in that it tended to restrict thought. Since it was possible to get a nearly pure measure of the factor called resolution, Dr. Hartline questioned whether perhaps this factor was not really brightness discrimination. He felt that on theoretical grounds a brightness discrimination factor was more likely to be pure than a resolution factor. His discussion raised the interesting possibility that hints for theoretical work in vision might come from the factor analysis of the AGO research. Dr. Hartline then made the point that perhaps individuals used in vision experiments should first be selected on vision tests which were pure in vari-

ous factors. It might be valuable, he said, to compare the visual performance of subjects who are clearly differentiated on various visual factors.

Colonel Lowrey remarked that he believed an incorrect impression had been given that vision testing in the Army and Navy was not satisfactory at present. He stated that he belived present testing procedures were quite satisfactory. Colonel Lowrey asked whether any studies had been made in which men were tested on the orthorater in various offices.

Dr. Sulzman replied that while he was still in the Navy, BuPers authorized the orthorater for classification, although BuMed did not accept it. Accordingly, men who came back from operations to be reclassified were referred to medical officers. It was found that in most cases men rejected by the orthoraters were passed by the medical officers. The question was accordingly raised whether the orthorater or the medical examination measured what was desired in the Navy. As a consequence of this need, a request for research had been originated which finally contributed to the founding of the AGO visual acuity study.

October 24, 1947

The Adjutant General
Department of the Army
The Pentagon, Washington, D. C.

Dear Sir:

The members, alternates, and associates of this committee wish to commend and express appreciation of the work accomplished by the Department of the Army, especially the Personnel Research Section of your office, in conducting the research reported in "Studies in Visual Acuity, Report of Progress, PRS Report No. 742".

The importance of this pioneer basic research cannot be overestimated. The findings reported will beyond doubt have profound effects on the kind and quality of visual examinations, both in the Services and throughout the civilian profession. The adoption of revised examining techniques which will inevitably result from this research will greatly increase effectiveness of manpower utilization in the Services. The excellence of the reports of this research has been a major factor in stimulating further similar studies and extensions thereof, both in the Services and in civilian research agencies. You are to be congratualted upon the fine job done so far.

This committee wishes to submit the following recommendations for your consideration:

1. That research on unexplored phases of the program be encouraged and facilitated.

2. That the report of progress (PRS Report #742) be published as an unclassified document and distributed as widely as possible, both to the Services and to the Civilian profession.

Sincerely yours,

Donald G. Marquis, Executive Secretary
Armed Forces-NRC Vision Committee

MINUTES OF THE MEETING

OF

THE SUBCOMMITTEE ON VISUAL STANDARDS

The Subcommittee on Visual Standards of the Army-Navy-NRC Vision Committee met at the Navy Department on August 26, 1947 at 10:00 a.m. The meeting was called to order by the chairman. The following were present: Dr. B. J. Wolpaw, 2323 Prospect Avenue, Cleveland, Ohio; Lt. Comdr. Ellsworth B. Cook, Medical Research Dept., U.S. Submarine Base, New London, Connecticut; Dr. H. S. Wigodsky, Aviation Medical Service, CAA, Dept. of Commerce, Washington, D.C.; Col. Austin Lowrey, Jr., (MC), Walter Reed Hospital, Washington 12, D. C.; Col. V. A. Byrnes, (MC), AAF School of Aviation Medicine, Randolph Field, Texas; Dr. Conrad Berens, Ophthalmological Foundation Inc., 301 E. 14th St., New York, N.Y.; Dr. H. A. Imus, ONR Navy Dept., Washington, 25, D. C.; Dr. W. A. Miles, 333 Cedar St., New Haven, 11, Connecticut; Dr. R. J. Wherry, Personnel Research Section, AGO, 1E 880 Pentagon Bldg., Washington, 25, D. C.; Dr. E. L. Green, Dept. of Zoology, Ohio State University, Columbus, Ohio; Dr. W. M. Rowland, Wilmer Institute, Johns Hopkins Medical School, Baltimore, Maryland; Dr. Louise L. Sloan, Wilmer Institute, Johns Hopkins Medical School, Baltimore, Maryland; Dr. E. R. Henry, Personnel Research Section, AGO, 1E 880 Pentagon Bldg., Washington 25, D. C.; Capt. J. H. Korb (MC) USN, Research Division, BuMed, Navy Dept., Washington 25, D. C.; Dr. J. H. Sulzman, 2705 15th St., Troy, New York; and Dr. Richard G. Scobee, Dept. of Ophthalmology, Washington University School of Medicine, St. Louis, 10, Missouri..

Dr. R. J. Wherry of the AGO presented a report on the Visual Acuity Testing program and its results. Just prior to his presentation, a partially completed report was placed in the hands of each one present. The report in printed form was incomplete in that the final summation of results and recommendations was not available. Dr. Wherry stated that the remainder of the report was "in press" and would be sent to each one in attendance within three or four days. The report was discussed, mostly in the form of questions addressed to Dr. Wherry for the remainder of the morning. It was the consensus of the group that no formal action be taken on the report until the complete printed form was in the hands of each member and each member had had time to study and digest it. It was agreed that the chairman would summarize the comments made on the basis of the incomplete report and send a copy to each member; members would then add any additional remarks after a careful study of the report and the opinion of the group would then be summarized by the chairman and sent to the parent committee. The group adjourned for luncheon.

At the afternoon session, two testing manuals were considered in the light of possible revisions. One was the Testing Visual Acuity Manual of Instructions and the other was the Manual of Instructions for Testing Heterophoria. The final form of the revised manuals was agreed upon unanimously.

It was decided to submit a recommendation to the Surgeons General urging the adoption by the armed forces of some instrument to be used for screening examinations In the opinion of the committee no instrument is available at the present time which is completely adequate. But there are at least two which could be modified somewhat to meet the requirements of the military services. A subcommittee was appointed to investigate modifications. Dr. Henry Imus was appointed Chairman and the other committee members were Dr. H. S Wigodsky, Dr. Edwin R. Henry, and Col. Austin Lowrey, Jr. (MC). The recommendation is a unanimous one from this subcommittee.

Respectfully submitted,

RICHARD G. SCOBEE, M.D., Chairman,
Subcommittee on Visual Standards.

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A SUMMARY OF RECOMMENDATIONS

ON VISUAL STANDARDS FOR THE ARMED FORCES

Richard G. Scobee, M.D.

The Subcommittee on Visual Standards and Testing met on March 10, 1947 and on August 26, 1947. Both meetings were held in Washington, D. C., and representatives of the Surgeon General of the Army as well as of the Navy were present. The basic consideration was a set of visual requirements for military and naval aviators and the following standards were suggested:

1. Visual Acuity. A discussion on visual acuity revealed that when Snellen devised his test chart, he considered that the minimum visual angle at which an individual with normal visual acuity could read at 20 feet was one-half minute of arc. Then he devised his letters, making them twice as large. It was considered that 20/20 requirement for applicants for flight training was quite liberal. Evidence was presented that aviators who returned from combat had a mean visual acuity of 20/15. It was voted that the minimum visual standard for candidates for aviation training be 20/20. It was stated further that visual acuity varies markedly with the conditions of the test chart, the illumination of the test chart, the illumination of the room and other factors. It was recommended that all visual testing rooms be standardized. It was found that the visual requirements for qualified military aviators differed between the Services to a minor degree, and it was recommended that representatives of the military services meet and agree upon visual standards for their various groupings of experienced aviators.

2. Refractive Error. It was revealed during the discussion on refractive error that more detailed study is needed in visual testing under dim illumination, in as much as at dawn and dusk an individual below a plus 0.50 D. and in mild myopia loses visual efficiency very rapidly. It was recommended that accepted candidates for aviation training have not more than 1.75 D. of hypermetropia of 0.75 D. of myopia in any meridian, nor more than 0.75 D. of astigmatism in any meridian when the accommodation is paralyzed by using one drop of 5% homatropine in one to 5,000 zephiran in each eye, three times, at intervals of ten minutes and then refracting the candidate 60 minutes after the first drop was instilled.

3. Accommodation. The maximum accommodative effort shall be within 3.0 D. of the normal limits according to age. The test should be done with letters in a plastic frame. The plastic must be clean and illuminated sufficiently to permit easy reading. Experienced aviators, if wearing corrective lens for flying, must demonstrate a minimum 2.50 D. of accommodation while wearing these lenses. If corrective lenses are not required, experienced aviators must demonstrate a minimum total of 2.50 D. of accommodation. It was further recommended that representatives of the Services meet and agree on accommodation for administrative aviators who fly only with a safety pilot.

4. Heterophoria. Candidates for aviation training will be tested at 20 feet and have not more than 5.0 prism diopters of esophoria or 3.0 prism diopters of exophoria, nor more than 1.0 prism diopter of hyperphoria. Subsequent studies have indicated that limits of 4^{Δ} s and 4^{Δ} x at 20 feet would include 95% of the population. Experienced aviators tested at 20 feet will have not more than 5 prism diopters of exophoria, 10 prism diopters of esophoria, nor more than 2 prism diopters of hyperphoria.

5. Depth Perception. To determine depth perception, the Verhoeff Stereopter will be used at a testing distance of 1 meter. Eight out of eight correct responses are required for passing. If the test is failed on the first presentation, the test shall be administered twice more and the subject is qualified on this test if two out of three presentations result in 8 out of 8 correct responses each.

6. Red Lens Test. Discussion on the red lens test revealed that good results cannot be obtained using the red lens now in trial cases. Specifications for this red lens were not at hand but have been previously recommended to both the Air Surgeon and the Bureau of Medicine and Surgery. Diplopia within 50° of the primary position which increases in the field of action of any extraocular muscle or group of extraocular muscles disqualifies. The red lens test shall be performed on all applicants for aviation training and on qualified aviators when the Medical Officer suspects a paresis or paralysis of any extraocular muscle or groups of muscles. If any paralysis or paresis of any extraocular muscle is found, the subject is disqualified.

7. Confrontation.

a. This test is to be performed as at present. Any evidence of abnormalities calls for a detailed study on the perimeter.

b. The examiner must be sure that his own peripheral vision is normal before performing this test.

8. Inspection of the Eyes. The instructions for the examination of the inspection of the eyes differs slightly between the services. It was recommended that representatives of the Services rewrite this portion incorporating desirable features of both.

9. Ophthalmoscopic Examination. Routine ophthalmoscopic examination shall be performed by the Medical Officer following the cycloplegic refraction. Any abnormalities that interfere with normal ocular function disqualifies.

10. Color Vision. Color vision testing is undergoing a period of revision at this time. Each of the Services uses the Pseudo-Isochromatic plates and each has developed a new color lantern. It was recommended that two tests for color defects be made available. At the present time, an individual who fails the Pseudo-Isochromatic plates is tested on the color lantern. It was recommended that further research establish the validity on various types of Pseudo-Isochromatic plates and color lanterns.

11. Associated Parallel Movements. This test will be performed routinely by the Medical Officer. If under- or over-action of any extraocular muscle or groups of muscles is noted, further study is indicated. Positive findings indicating paresis or paralysis of any ocular muscle or groups of muscles disqualifies.

12. Nystagmus. Nystagmus disqualifies if it is demonstrated in the primary position or in the upper or lower fields of fixation, except in the extreme lateral position of the eyes.

13. Prism Divergence. Considerable discussion elicited the fact that individuals with a low prism divergence have marked difficulty in performing near work. Since an aviator must attend ground school and has considerable administrative duties involving much reading, it was recommended that applicants for aviation training have the prism divergence of not less than 12.0 prism diopters.

Tests to be eliminated:
1. Binocular Visual Acuity
2. Interpupillary Distance
3. Near Point of Convergence
4. The Howard-Dolman Test.

This conference revealed that the visual requirements for military aviators in the Services are very similar. The chief differences occurred mainly in the grouping of experienced pilots and in visual requirements for flying personnel other than pilots. It was recommended strongly that representatives of the Services meet and write that portion of the chapter "Aviation Physical Examination" concerning visual requirements and that both Services use exactly the same terminology and grouping for flying personnel of all categories.

The two manuals on Procedures, one for testing heterophoria and the other for testing visual acuity, were re-studied and a few minor changes made. These manuals are considered to be in final form at the present time.

One change of particular interest to this committee was that of a standard for illumination of the testing room when visual acuity is measured.

An earlier decision had been to have a gray binding on the Visual Acuity Testing manual. The binding was to be the exact shade of gray required for the walls of the testing room. The Subcommittee was of the opinion that the idea of a "cover" color standard was impractical for two reasons: (a) it would change color with the passage of time and (b) it would be expensive to reproduce the exact shade desired.

In searching for a substitute for the "cover" idea several possibilities were considered. It was finally decided to paste on one page of the manual three shades of gray from the Munsell color series, one shade to be the exact color specified and the other two to represent the allowable limits of variation. It was pointed out that the navy shirt was the proper shade of gray, but it was deemed inadvisable to send shirt samples because of (a) expense and (b) general destructiveness to shirts.

The present tests and testing techniques employed in the military examination of the visual functions are satisfactorily reliable <u>if</u> properly performed by experienced examiners. They are also time consuming.

In time of war, it becomes necessary to examine large numbers of men in a short period of time. This necessitates the rapid and hence necessarily superficial training of a group of examiners sufficient to accomplish the task. Certainly there is not sufficient time to permit the individual examiners to gain the experience absolutely necessary to the proper performance of some of the tests. Even the best examiner requires a large examining area and perhaps 15 minutes per subject at a minimum.

If there is to be another war, the time available for mobilization will obviously be short. Any method of testing large groups of men with a reasonable degree of accuracy in a shorter period of time than is possible with present tests would be highly desirable.

A screening device which would incorporate the majority of the tests of the visual functions into a single machine would be of inestimable value, provided it were satisfactorily reliable. Two machines, the Orthorater and the Sight Screener, are approximations of the ideal although both are far from perfect. It seems reasonable to suggest that such a machine could be developed with satisfactory tests.

If this were done, large groups of men could be tested in a short period of time. The use of a machine would eliminate a large percentage of examiner errors which have been present in the past and which seem unlikely to be eradicated completely with the clinical testing techniques.

The above recommendations were submitted to the Surgeons General of the Army and of the Navy. A subcommittee, headed by Doctor Henry Imus, was appointed to consider specific recommendations for the development of such a screening device or for modifications of existing instruments if feasible.

DISCUSSION:

Colonel Lowrey commented upon the relation between phoria and age. He felt that lateral phorias decreased with age whereas vertical phoria increased with age. He felt that when young patients come into the office, insufficient time is spent to obtain a valid measure of the phoria that really exists.

Dr. Scobee replied that the limit which has been suggested, now 1 diopter, might well include the normal variations which could be considered adventitious. The value of 1 diopter agrees with the figure to be expected on theoretical grounds.

Dr. Rowland stated his agreement with Dr. Scobee. He stated that a patient with 1 diopter of hyperphoria does not possess symptoms, but that patients with hyperphoria can be detected with proper tests.

Colonel Lowrey reported that the NRC Committee on Ophthalmology recommended that West Point accept applicants with as much as 2 diopters of hyperphoria. It was Colonel Lowrey's opinion that such applicants will show at least 3 diopters at the age of 30-35. At the age of 40, he would expect even more hyperphoria.

Dr. Scobee commented that there were no data available to his knowledge, bearing upon the variation in hyperphoria with age. He felt that if anyone suspected an increase in hyperphoria with age, then applicants showing any hyperphoria should be eliminated for safety.

Dr. Imus made the point that the recommendations of the Subcommittee were intended for men in general service and not for aviation.

Colonel Lowrey replied that the recommendations of the NRC Committee on Ophthalmology were intended for applicants at the Naval Academy and at West Point of whom a certain percentage go into aviation. He also emphasized that aviation does not put the individual with hyperphoria to the most severe test. Sitting at a desk is a much harder strain upon the individual with hyperphoria.

Dr. Scobee remarked that the Committee on Ophthalmology was to have considered five sets of recommendation, but that they did not get around to the set of recommendation for the Air Forces.

Dr. Miles asked whether the Subcommittee had considered the special problem of photophobia. The problem had arisen, Dr. Miles said, in connection with the specification of sunglasses.

Dr. Scobee replied that the Subcommittee had not considered the problem of photophobia.

Colonel Lowrey asked whether the Subcommittee intended to include tests for night vision.

Dr. Scobee replied that night vision testing had been discussed and that it was agreed for specification purposes night vision testing would be necessary. He pointed out that the inclusion of night vision testing in a general screening instrument would prolong unduly the length of the testing period which was directly counter to the aims of the Subcommittee. Dr. Scobee stated that the working group at the Wilmer Institute will consider tests of night vision along with other tests, but that no specific recommendations by the Subcommittee were available on this subject at this time.

Dr. Fry asked whether any consideration had been given to phoria testing after occlusion.

Dr. Scobee discussed briefly the history of testing phoria after occulsion. He concluded that such testing leads to erroneous results since anyone's eye tends to turn out and up upon prolonged occulsion. He believed the test was highly unreliable.

Colonel Lowrey raised the problem of testing with machines in test centers removed from electricity.

Captain Shilling remarked that the intention was to utilize the machine testing at the time of admission to the services at induction centers.

Dr. Sulzman emphasized the importance of having a standard instrument as a general screening device. He reported that the ordinary clinical test does not lend itself to such standardization.

To: The Surgeons General, Army and Navy, and The Air Surgeon.

Subject: Recommendation of a Visual Screening Instrument.

The present tests and testing techniques employed in the military examination of the visual functions are satisfactorily reliable if properly performed by experienced examiners. They are also time consuming.

In time of war, it becomes necessary to examine a large number of men in a short period of time. This necessitates the rapid and hence necessarily superficial training of a group of medical examiners sufficient to accomplish the task. Certainly there is not sufficient time to permit the individual examiners to gain the experience absolutely necessary to the proper performance of some of the tests. Even the test examiner requires a large examining area, such as a twenty-foot testing range, and a minimum of fifteen minutes per examinee.

If there were to be another war, the time available for mobilization will obviously be short. Any method of testing large groups of men with a reasonable degree of accuracy in a shorter period of time than is possible with present tests would be highly desirable.

It is the opinion of this Sub-Committee that a screening device which would incorporate the majority of tests of the visual functions into a single instrument would be of inestimable value, provided it were satisfactorily reliable. Two machines already on the market, the Orthorater and the Sight Screener, are approximations of the ideal although both are far from perfect. It seems reasonable to suggest that such a machine could be developed with satisfactory tests. If this were done, large groups of men could be tested in a short period of time. The uses of a machine would eliminate a large percentage of examiner errors which have been present in the past and which seem unlikely to be eradicated completely in the future with the clinical testing techniques now in use.

This Committee stands ready to sponsor such a project if the proper authorities see fit to approve it and urge that serious consideration be given to the proposal.

Respectfully submitted,

RICHARD G. SCOBEE, M.D.

Chairman, Subcommittee on Visual Standards and Testing.

REPORT OF THE COMMITTEE ON THE INSTITUTE FOR RESEARCH IN VISION

Introduction

Man depends upon vision more than upon any other single sense for knowledge of and adaptation to his environment. But in spite of this fact, vision is such a universal function and is used so continually that to the average man it becomes commonplace. For the normal individual the process of education depends largely upon the sense of sight. In industry it is essential that the worker distinguish accurately between moving and non-moving parts of a machine. His safety and in many cases even his life depend upon the keenness of his visual discriminations. The interior decorator attempts to influence man's moods and mental processes by different colors and combinations of colors. The larger part of man's recreation, such as the playing of games, the enjoyment of the theater and the movies, depends largely upon the sense of sight. It is evident that vision plays a major role in human welfare. But if vision is to play this important role effectively, extensive and fundamental research in this field is essential.

Present Status of Research in Vision at Ohio State University

Here at the Ohio State University, we have in progress at the present time major research projects on different aspects of vision in the Departments of Psychology, Fine Arts, Education, Zoology, Optometry, Physics, Electrical Engineering and Ophthalmology. Some of these projects are listed below.

The staff of the School of Optometry has published more than 50 papers on various visual problems. Dr. Glenn A. Fry and his associates are at the present time engaged in important research on such subjects as accommodation, convergence of the eye, and color vision.

Dr. Claude S. Perry of the Department of Ophthalmology is cooperating with Dr. John H. Helwig of the College of Veterinary Medicine in the preparation of a series of colored photographs of the retinas of various domesticated animals. Such photographs of the retina have never before been made and when this project is completed, it will constitute an outstanding contribution to our knowledge of the comparative anatomy of the retina.

Dr. Samuel Renshaw in the Department of Psychology rendered a major service to the armed forces during the recent war in connection with training for the rapid perception and identification of air and surface crafts. He is at present engaged in similar research having to do with the discrimination and recognition of pips on radar screens. At Don Scott Field, a study is just being completed by Drs. Floyd Dockeray and Gorham Lane on the validity of present visual standards in the selection of aviators.

In Fine Arts, Professor Hoyt Sherman has developed a technique for training and improving the visual perception of his students. Dr. Ross Mooney of the Department of Education is developing the educational aspects of this work. They are coordinating their work with that of similar laboratories elsewhere and have been working in close association with Professor Adelbert Ames of the Dartmouth Eye Institute.

Dr. H. W. Nisonger of the Bureau of Special and Adult Education is initiating a study of the validity of various visual screening tests for chilren He is being assisted in this work by Dr. Thomas E. Shaffer of the Department of Pediatrics. The immediate purpose of this investigation is the selection of a uniform test which

it is hoped that state Department of Education will require in all schools of the state.

Dr. V. C. Dethier of the Department of Zoology and Entomology has carried on investigations on the optical apparatus of larval insects and is the author of several important papers in this field. While he is not at the moment engaged in research in this field, he still has a major interest in it and would welcome the opportunity to pursue his investigations further.

Professor K. Y. Tang of the Department of Electrical Engineering has carried out an interesting investigation on illumination. While no work in this field is in progress at the present time, it is an important subject and one in which further investigation should be encouraged.

Dr. Arthur Culler, who has recently joined the Department of Ophthalmology, has extensive plans for investigations on various diseases of the eye. It is hoped that this work will get under way in the immediate future.

It is the concensus of opinion of ophthalmologists that approximately eighty per cent of all visual defects are hereditary in nature. This fact indicates the desirability of a comprehensive investigation of hereditary factors in all diseases and anomalies of vision. The Department of Zoology here at Ohio State is well equipped and staffed for such an investigation and is deeply interested in the problem. Active work on the preliminary stages of such an investigation will, it is hoped, soon be initiated.

In view of the extensive and varied nature of research in the field of vision that is at present under way or contemplated here at Ohio State, it seems desirable that there be established an organization whose function it should be to foster, support, and coordinate such investigations. The complex nature of modern research makes cooperation essential. An otherwise fine piece of research may be incomplete and exhibit glaring imperfections all for the lack of cooperation with competent investigators in related fields.

Recommendations

I. Name. This committee therefore recommends that such an organization be established and that it be known as "The Ohio State University Institute for Research in Vision."

II. Functions. The functions of this organization would be as follows:

First: To sponsor research in this field, to provide opportunities for cooperative investigations by various groups, and to obtain financial support for such research.

Second: To hold periodical meetings for the discussion of the various research programs in progress.

Third: To hold symposia on vision at which members of our own staff and distinguished investigators from other institutions would speak on various aspects of vision.

III. Organization. It is the opinion of the committee that research in vision falls naturally into four fields as follows: biological, medical, physical and social. It is, therefore, recommended that the governing body of the Institute consist of an

executive committee to be made up of one man representing each of these four major fields. It is further recommended that the chairman of this executive committee be the director of the Institute. The executive committee should have as its function the conduct of the routine business of the Institute, the organization of cooperative groups for carrying on research involving several fields, the allocation of available funds to the different investigators and the solicitation of outside financial support for the various projects that are undertaken. The members of the executive committee would not necessarily be actively engaged in research in vision, but should be men who are essentially research-minded and who are in general familiar with the field and capable of judging the relative importance of projects in the various aspects of the field, and could, therefore, be trusted with the fair and impartial distribution of funds to the different phases of the program. Since one of the functions of this committee would be the solicitation of outside funds for the support of research, it is the feeling of the committee that one member of the executive committee should be a man capable of serving in the capacity of public relations officer. It is further recommended that the Dean of the Graduate School be, ex officio, a member of the executive committee, and that the members of this executive committee, including the director of the Institute, be appointed by the President upon the recommendation of the Dean of the Graduate School.

In addition to this executive committee of five members, it is recommended that there also be a larger governing body known as the Council which should consist of one representative from each area on the campus actively engaged in research in vision. The Council should function as the policy-making and legislative body of the Institute. Initially the Council should contain representatives from the following areas: Education, Electrical Engineering, Fine Arts, Ophthalmology, Physics, Psychology and Zoology. Representatives from other areas should be added as such areas initiate research in some aspect of vision. The members of the Council should be appointed by the Dean of the Graduate School.

IV. Finances. While it is the hope of the committee that after its organization, the Institute for Research in Vision will be able to obtain substantial financial support from outside sources, it is nevertheless true that the University should assume the responsibility for the financial support of much of this research program. However until such financial support from the University, as well as from outside sources, is forthcoming, it is the hope of this committee that such funds as are necessary for the organization and initial development of the Ohio State University Institute for Research in Vision can be furnished from the budget of the Graduate School.

April 30, 1947

Respectfully submitted,

Harold E. Burtt
Glenn A. Fry
Claude S. Perry
Alpheus W. Smith
Fred A. Hitchcock, Chairman

[redacted]

SUMMARY OF RECOMMENDATIONS

I. NAME

Ohio State University Institute for Research in Vision

II. ORGANIZATION

A. Director appointed by the President upon the recommendation of the Dean of the Graduate School.

B. Executive Committee

1. Membership

   The Director of the Institute who acts as chairman of the Committee, the Dean of the Graduate School, and three additional members appointed by the President upon the recommendation of the Dean of the Graduate School. This committee should include a representative of each of the following aspects of the field of vision: biological, medical, physical, and social.

2. Functions
   - a. Conducting the routine business of the institute.
   - b. Obtaining and distributing funds to support research in vision.
   - c. Organization of cooperative groups for research involving several fields.

C. Council

1. To consist of one representative from each area on the campus actively engaged in research in vision. At present the council should contain a representative from Education, Electrical Engineering, Fine Arts, Ophthalmology, Optometry, Physics, Psychology, Zoology, members of the council to be appointed by the Dean of the Graduate School.

2. Function

   Legislative and policy determining body of the Institute.

III. FINANCES

1. The University budget.

2. Outside support.

3. During organization and initial development, funds from the Graduate School.

[redacted]

DISCUSSION:

Dr. Imus asked Dr. Hitchcock whether his plans would include a central laboratory where cooperative research problems could be carried out by various members of the departmental vision staffs, or whether each department would carry out its own research in its own laboratory.

Dr. Hitchcock replied that it was the intention of the plan that such central laboratories be set up. No such facilities are at present available. However, the School of Optometry has a fund of $300,000 for a new building and it is expected that central facilities for research could be included.

Dr. Imus asked whether it was intended that a nucleus research group would be set up to work together in the new building. Would there be physicists, physiologists, optometrists, and others, stationed in the building, formulating, conducting, and evaluating research together?

Dr. Hitchcock replied that it was his personal opinion that there should be such a group.

Dr. Miles commented that the Ohio State plan sounded very feasible in that it would provide for interlaboratory loan of equipment. He asked whether the feasibility of having a small group of experts on experimental design has been considered.

Dr. Hitchcock replied that the Executive Committee of the Research Center including as it does, a medical man, a biologist, a physiologist, and a social scientist, would be such a group.

Dr. Marquis commented upon the long and comprehensive list of research in vision already going ahead at Ohio State. He asked what the institute would add to the already existing researches.

Dr. Hitchcock replied that the center would serve to coordinate the various groups. It would provide facilities and funds for research. The institute could recommend cooperation between various scientists on a single research problem.

Commander Brown recommended that a planning board be set up in connection with the center to keep in touch with various vision research groups, many of which were represented on the Vision Committee, so that an over-all program of visual research could be carried on without duplication or neglect.

Lt. Commander Farnsworth commented that the organization of universities in general does not aid the individual research man in his laboratory work. He felt that perhaps the Ohio State Institute would merely "multiply paper work and add meetings to people already burdened". Such a function would add very little to the work of an active scientist. He pointed out that all universities are organized to bring together specialized workers in various fields in such a way that they can at any time call upon each other for advice.

Dr. Scobee commented that the Vision Committee has done a very good job so far of bringing to the attention of investigators the work of others in relating fields. He pointed out that research men are "rather peculiar" in that they become obsessed with an idea and will carry it out no matter where they are or how long it takes. He questioned whether an investigator at one university would be willing to disrupt his work in order to go to Ohio State.

Dr. Ogle commented that the value of an institute of this sort lies in its permanency and in its hiring a permanent staff. He emphasized the need for security if a man is to be able to conduct research.

Dr. Fry remarked that the matter of permancy had been considered in the plans for the institute. He pointed out that vision is rather unique in so far as academic circles are concerned in that there is no real "home" for it on a university campus. He expressed his belief that an institute within a graduate school would be the proper environment for vision research.

Dr. Dimmick raised the question of the instructional realtionship of the institute to the university. He pointed out that unless there is instruction in vision new researchers will not continue to come along.

Dr. Hitchcock replied that the plans for the institute had been concerned chiefly with the research angle. He pointed out that since members of the institute would be regular members of various departments, instruction would be taken care of through regular departmental channels.

Dr. Sloan asked whether the institute might not consider publishing a journal for vision research alone. She expressed her belief that there was sufficient material in vision so that a single journal collection would be possible and valuable.

Dr. Viteles reported that the Committee on Aviation Medicine of NRC has been asked to work on airport landing systems. He expressed the belief that if the Ohio State Institute were set up, it would be an ideal place to conduct the landing systems research.

REPORT OF THE ROSCOMMON VISIBILITY TESTS

H. Richard Blackwell
University of Michigan

INTRODUCTION

During the war years, a comprehensive experimental program was set up under NDRC to evaluate the visibility of objects of military importance. As originally planned by Professor A. C. Hardy, the program was to include complete determination of the two factors concerned in visibility: attenuation of light by the atmosphere and response to light by the human eye. Both aspects of the program were investigated by the L. C. Tiffany Foundation, the experimentation continuing over a period of more than two years. The response data of the human eye obtained have been reported by the speaker, both to this group and in the scientific literature. The studies made of the attenuation of light by the atmosphere have been reported both to this group and other scientific groups by Professor S. Q. Duntley. Nomographic charts were prepared at the close of the NDRC program embodying the response data of the eye and Koschmeider's formulation of attenuation of light by the atmosphere. Also, a special treatment of the scattering of light along a slant path developed by Professor Duntley was built into additional nomographic charts.

The NDRC nomographic charts of visibility have been introduced to this group by Professor Duntley, and have been made available in limited supply to various members of the Committee. The nomographs are also available in a newly published volume, The Summary Technical Report of the NDRC Camouflage Section. Combining as they do response data for the human eye obtained in the laboratory with the Koschmeider formulation for atmospheric attenuation, the nomographs represent data from two types of experimentation, but they do not represent the results of actual field trials. Time did not allow for field trials during the NDRC program.

When the NDRC nomographic charts are presented to engineers and other operational personnel, their natural reaction is to question whether the predictions of the nomographs have been put to actual field test. Up until the present time, such field experimentation had never been attempted.

A field test of the NDRC nomographs involves the validity of each of the two types of information which make up the charts. In the case of attenuation of light by the atmosphere, there is first of all the problem of the general applicability of Koschmeider's formulation to various types of atmosphere. In addition, since the nomographic charts cannot be used without a value for the attenuation coefficient of the atmosphere, instruments used in determining this coefficient must be balidated in order to be certain that the quantity measured by them predicts accurately contrast reduction of visual stimulus objects. Validation of the eye response data is necessary also because of the many differences in conditions between the laboratory and the average field situation. These conditions include, for example, such variables as nonuniformity of stimulus objects and of the visual field, the gross difference of appearance of objects in the laboratory and the field, and the presence of stimulus fluctuations in the field caused by atmospheric boil or shimmer.

The number of possible causes for discrepancy between the NDRC nomographic charts and actual field conditions is seen to be quite large. It therefore appeared desirable that the variables be isolated somewhat so that more definitive results could be obtained in preliminary field experiment. A working group consisting of Professor S. Q. Duntley, Professor Hans H. Neuberger, DR. Howard S. Coleman, and the speaker began to make tentative plans for field experiments to test the

validity of the NDRC nomographic charts for field use. It was agreed that the task should be broken into two parts, Dr. Coleman's group being concerned with the attenuation of light by the atmosphere, and the staff of the Vision Research Laboratory at the University of Michigan concerning themselves with the problem of the eye response.

Accordingly, the Roscommon visibility tests were set up to test only the problem of the val idity of laboratory eye response data for use under field conditions. In order to isolate the two problems, the Roscommon project prepared always to measure the stimulus reaching the human eye. The stimulus required for successful visual detection in the field was then to be compared with corresponding stimulus values required in the laboratory.

RESEARCH FACILITIES

The first requirement for the outdoor visibility tests was that stimulus objects of controlled size and brightness be introduced in the visual field above the horizon line. To achieve this objective, one must either work over open water or else with targets erected on hill tops against the sky. It was decided that the initial field tests should be run over land to simplify various operational problems. It was required, therefore, that means be provided for suspending target objects above the tree line on various hilltops. Forest fire lookout towers appeared the logical means for such target presentation. After some inquiry, a series of fire lookout towers located near Roscommon, Michigan, and belonging to the State Department of Conservation, was located. The towers were made available to the project through the generous cooperation of the Conservation officers.

A central fire tower was selected as an observation post. Located around this tower, at varying distances, were thirteen fire towers, each visible against the sky. The ground between towers was nearly uniformly covered with forest. Before actually commencing the project, it was planned that some six or seven of these towers be used for observations with naked eye and with binoculars, by night and by day. Construction problems reduced the number of target towers used to three. It was planned that large billboard type targets with continuously variable contrast be prepared and mounted on the several lookout towers. In addition, plans were made to utilize search-lights as targets for the night observations. A staff of seven young men was assembled for the Roscommon mission. Housing was arranged at a camp on Higgins Lake near the central lookout towers.

As soon as the project was begun, the magnitude of two problems became fully apparent for the first time. The first problem was that of the horizontal dimension of space. The lookout towers selected for target posts were located at airline distances up to 20 miles from the observation post. It soon became apparent that winding country roads increased the distance between towers to a rather staggering degree. Two jeeps and a pickup truck were furnished the project by the Navy and a second truck was obtained from the University. During the three months of the project, these vehicles were driven more than a total of 25,000 miles.

The second problem involved the vertical dimension of space. Each fire lookout tower rose some 100 feet from the ground,and it was at such heights that we proposed to mount our targets. Members of the staff soon became resigned to the life of steeplejacks. Figure 1 should indicate the nature of the problem. This is a picture of a typical lookout tower. Sixty-five feet above the ground, there is located a wooden platform. This platform was constructed by the project crew and approximately a ton of equipment was mounted thereupon. Notice the absence of civilized means of ascent. Above the platform we see one of the billboard type

targets. This target measured 6 x 12 feet and is capable of having a constantly variable reflectance when viewed from the observation post, in this case 6 miles away. The variation in reflectance was produced by a venetian blind arrangement. As seen in Figure 2, the target consists of a black billboard in front of which are mounted white vanes which can be rotated from vertical to horizontal. Since the entire target is below the resolution limit of the human eye as viewed from the observation post, variation in the amount of white vane present varies the integrated reflectance of the target. As the target reflectance is varied, the target's brightness varies from a point greater than the sky to one less than the sky, provided the illumination from the sun is sufficiently great. A given target could be used only either morning or afternoon since direct illumination from the sun is necessary to the successful operation of the target. The position of the vanes was controlled by a lever arm mounted on the tower platform. A searchlight was also mounted at this tower installation, 6 airline miles from the observation post.

The first task of the project crew was to construct three such platforms and target assemblies. A second installation is shown in Figure 3. This tower was 10 airline miles from the observation post. The third one is shown in Figure 4. This tower was 20 airline miles from the observation post. The observation post was the only tower well suited to receive visitors. It alone was provided with a staircase and handguard. A view of the observation post is given in Figure 5. In this installation, there was a trap door leading into the platform which provided a means of securing the installation against vagrants.

Communication was maintained between the towers with Army radio equipment. The project ran three stations, having an FM license for 60 watts. Very satisfactory communications were possible between all the target towers and the observation post, or from target tower to target tower. Only two fixed radio installations were used, the third station being mounted in one jeep as a portable unit. The radio sets were operated from storage batteries. Since no power was available at the lookout towers, motor generator sets were obtained from the Navy to maintain the storage batteries.

The first problem encountered after installations were complete arose from the desire to present a target in the midst of a uniform portion of sky. It was desired that the target appear to be suspended in space without visible support so that the tests would measure visual detection rather than a change in the appearance of an always visible object. The billboard type targets were extremely small with respect to the total height of the towers. Calculations from laboratory data had indicated, however, that the compactness of the target would render it more visible than the entire spider-legged tower structure. This prediction was found to be universally true. However, the tower structures were often quite visible under many of the atmospheric conditions encountered. It was therefore necessary somehow to obscure the tower structure without rendering the target less visible. It was finally decided that the tower structure could best be obsc ured by painting it so that during a substantial portion of the day its brightness would be a good match with the horizon sky. The simplest means of obtaining a delicately adjusted reflectance was to paint white stripes around the tower structure. These stripes, integrated with the gray patches left unpainted, could be made to produce just the right reflectance for match with the sky by varying their width.

In Figure 6 we see two of the project crew applying white paint to a tower structure. At 100 feet above the ground, this becomes rather a difficult performance. It was found that there was usually a one to two hour period during which each of the towers was invisible after careful painting. The most difficult part of the tower to obscure was the tower cab. As we see in Figure 7, the same device

of white and gray stripes was used.

The most difficult problem encountered in the project was the successful recording of the small amounts of light necessary for threshold detection by the human eye. Because of the large amount of atmospheric boil present over the long distances used in this experiment, it was obligatory that recording of the stimulus value be accomplished in extremely brief and frequent intervals of time. Motion picture photography immediately suggested itself. The optical system used included a 30 power telescope and a standard Navy 16mm. gun camera. It was possible to obtain reasonably adequate photographic records of the targets, with this equipment. Because of the high magnification, it was necessary to provide a rigid support for the photographic equipment. A height finder tripod was prepared specially for this purpose by Dr. Howard Coleman of Pennsylvania State College. Considerable difficulty was encountered in providing a calibration for each frame of the photographic record. The standard technique of inserting a "gray scale" in the field of the camera was not feasible since it would involve construction of a number of special towers of 50 to 60 foot height. Instead, a special optical system was used which produced a series of calibration brightness upon each frame. Fram these known brightnesses, the gamma of the photographic material for each frame could be computed. The tripod, telescope, camera, and calibration system are shown in Figure 8. A second view of the equipment is given in Figure 9 with lens shade and masking cloths in place.

The psychophysical procedure used in the experiments was chosen for complete comparability with the laboratory procedure used in the Vision Research Laboratory. With this method, each target presentation includes four time intervals, in only one of which a stimulus appears. It is the task of the subject to report in which interval the stimulus appeared, and the subject is forced to guess the most likely time interval for each stimulus presentation even though he may not feel certain of his response. The speaker has reported previously to this committee the experimental finding that this type of psychophysical procedure insures valid results whereas the more usual yes-no procedure does not. The exact duration of each of the time intervals was standardized by means of metronomes mounted in each of the lookout towers. Members of the project crew followed a predetermined sequence in presenting stimuli to the observer. With the billboard type targets, the vanes were first set at a position which would render the target invisible against the horizon sky. The tower man operating the vanes was in radio communication with the experiment monitor in the observation post. The monitor in the observation post used 10-power binoculars in setting the invisibility point so that an extremely precise setting was possible. The vanes of the venetian blind target were then set to provide a bright stimulus of sufficient magnitude to be detected approximately 50% better than chance. This setting of the vanes was also made upon instructions from the monitor in the observation post. Having set the two positions of the vanes for invisible and stimulus, the tower man began his series of presentations, calling the numbers of the presentations over the radio set. The tower man also indentified each of the four time intervals at each target presentation. In Figure 10 we see the apparatus for positioning the target vanes. There is a lever arm connected with the vanes. Two limiting blocks were placed as shown in Figure 10, corresponding to the invisibility point and to the stimulus point respectively. The tower man had merely to alternate the lever arm between the two alternating positions set by the blocks. For example in a trial where the stimulus was to occur in the second time in interval, the operator pushes the lever arm up as he says 1. He holds the arm in the up position during the first time in interval, thus setting the target at the invisibility point. At the count of 2, he pushes the arm down against the lower block and holds it in the position during the second time interval. At the count of 3, the arm is again raised where it is maintained

through the third and fourth time intervals. In this way, there was presented only one stimulus value, during the second time interval. In the next trial, the stimulus would probably occur in some other time interval and so on through a series of 20 presentations of a given stimulus value. During the entire sequence of trials, the monitor in the observation post watched the target through 10-power binoculars. He recorded the observers' responses as well as the true responses and was therefore able to evaluate the psychophysical data obtained.

In Figure 11 we see the speaker acting as monitor. In Figure 12 we get an overall view of the observation post in action. At the upper left we see the monitor seated at the radio set with binoculars in position. At the lower right-hand corner we see the telescope and tripod mount. Toward the upper center section, we can detect the observer in the act of making observations. The experimental procedure followed this order: the target vanes were set for invisibility and the monitor estimated the value of the stimulus which would be detected approximately 50% better than chance. A series of twenty observations was made, utilizing the same stimulus each time. The responses were scored and appropriate changes were made in the stimulus so that percentages both greater and less than 50% were obtained with successive values of the stimulus. It was never possible to obtain more than 80 observations in a given session because of the change in conditions related to the changing position of the sun. For this reason, the collection of data was a slow and uncertain affair. The presence of clouds made observation nearly impossible. Since the daytime experiments depended upon the sun's illumination for lighting the target vanes, experiments could not be conducted under fog or hazy conditions.

Installing a standard Navy signalling searchlight in one of the towers was a comparatively simple matter. The face of the searchlight was masked down to 4 inches square so that reduction of the searchlight intensity could be produced by standard laboratory gelatin filters. The vanes of the signalling searchlight were then used to shut off the stimulus in the same type of temporal sequence used with billboard targets. Searchlight experiments were conducted at night when the tower was completely obscured.

To achieve the objective of the experiments, it was necessary that the observers determine their threshold in the laboratory and in the field under similar conditions. For this purpose, a special room was prepared in the Vision Research Laboratory and the threshold intensity of point sources was determined for day and night brightness levels with the naked eye and with standard Navy 5 X 50 binoculars. These laboratory conditions corresponded to the day and night tests in the field since all targets used were below the resolving limit of the eye.

In order to calibrate stray light in the optical system of the photographic recorder, known point source intensities were photographed in the laboratory with the entire optical assembly later mounted on the tripod in the field. Since photographic record was made near threshold intensity both in the laboratory and in the field, the photographic technique was a null photometer. In addition, it was possible to obtain absolute values in the laboratory so that the absolute intensities required for threshold could be computed.

Let us turn now to samples of the motion picture records obtained. First we see the 6-mile target; as the vanes are turned slowly and continuously, the target varies from brighter to darker than the horizon sky. Observe that the tower structure is quite visible. To the naked eye, however, the structure was not visible when the photographs were made although the eye could see the target at each extreme value as being clearly brighter and clearly darker than the sky respectively. In

order to minimize the influence of the tower structure which, although invisible to the observer, did not match the horizon sky, each tower was used only when the visual threshold occurred near maximum contrast of the bill board target. Under these conditions, the target contrast was so great compared to the structure contrast that no appreciable error would be introduced by ignoring the structure contrast. The 6-mile tower was used, therefore, only on hazy days. Final data were all obtained on clear days and hence none were obtained with this target.

Next we see the 10-mile target, varying from brighter to darker than the sky. In the photographs made with the target at highest contrast, we can see some "squirming" of the target produced by atmospheric conditions.

Next we see the 20-mile target maintained at maximum contrast. Observe the poor definition of the image but little apparent change in size or brightness of the image of the target.

We see now the Navy signaling searchlight located on the 6-mile tower. The pictures were made under conditions in which the tower structure was invisible. The fluctuations of the searchlight were apparent to the unaided eye.

We see now similar conditions on a second day. On this occasion there was a temperature inversion caused by a polar air mass, with increased atmospheric turbulence. Notice the greater magnitude of the fluctuations.

In the preceding photographs, the full diameter of the searchlight, twelve inches, was used. The photographs shown now were obtained with a 4" diameter stop placed over the face of the searchlight. Observe the enormous increase in fluctuations. The size and shape of the searchlight appear to fluctuate violently.

We turn now to similar photographs taken at 9:30 P.M. of the same day on which the first searchlight photographs were taken. The full twelve inch diameter of the searchlight is used. Notice the relatively small fluctuations.

Our last photographs were taken after midnight the next day, with the searchlight stopped down to a four-inch diameter. Observe the large scale fluctuations just as were observed in the daytime.

A simple experiment was conducted at the time the last night photographs were taken to investigate the cause of the enormous fluctuations observed. The candlepower distribution from the searchlight used is quite steep. If non homogeneities existing in the atmosphere act like prisms, as has been frequently supposed, we might expect reduction in intensity by atmospheric deviation of the beam and consequent shifting of the candlepower distribution. If, however, the candlepower distribution were spherical, then prismatic action would not reduce candlepower over a wide range of deviation.

To test this prediction, a near perfect diffusion was introduced at the front face of the searchlight. The magnitude of fluctuations was not affected. A psychophysical test was made to establish this fact by requiring two observers to report which of two conditions showed less fluctuation: the diffusion set-up or the searchlight reduced to the same output by gelatine filters. Responses were never better than chance.

The exact mechanism of these fluctuations is not clear to the speaker. Perhaps there are simple density differences due to thermal gradients. This explanation does not seem adequate since the searchlight appeared to change size

during fluctuations. Perhaps atmospheric particles act like lenses which change the effective focal length of the eye lens or other lens used to record the phenomenon.

Let us turn now to the threshold data obtained in our limited number of experiments. Observations of billboards by day were made on three occasions, and on two occasions observations of searchlights at night were made. In each case, the physical measure of the stimulus was the average flux difference between stimulus and background. For the daytime readings, there was no reliable variation in flux from moment to moment, although some records seem to show changes of shape in the targets at 10 and 20 miles. More precise recording will be becessary to quantify such variation. Gross variations in flux difference were, of course, present in the photographic records made at night, but here too the average value was used.

Comparison between laboratory and field data is possible from the data of Table I. It is obvious that the number of observations made both in the laboratory and in the field is extremely small. It was not possible to begin experiments until two weeks before the termination of the project due to the difficulties of construction. Within the limits of the data, however, it is apparent that there is no systematic difference between thresholds in the field and in the laboratory. It is interesting to observe the rather good agreement between these data and the laboratory data obtained by the speaker at Tiffany.

The summer results are by no means definitive since the number of observations is small. In addition, all the tests were made during a two-week period of extremely clear air so that generalization to other weather conditions is not justified. For this reason, it seems desirable that the experimental work be continued during the summer of 1948. Certain changes in apparatus and procedure will be made. The size of the image produced on the motion picture film was scarecely larger than the resolution limit on the film. It is proposed that an additional factor of five in magnification be utilized. The use of 16 mm. film was adopted for purposes of economy. However, the calibration of each frame of the film record must occur too near the edge of the film for high reliability. It is planned accordingly that 35 mm. film will be used in the 1948 tests. With the installations practically ready for operation next summer, it should be possible to obtain data over a period of twelve weeks. In this period, it should be possible to collect definitive data.

In view of the encouraging results obtained this summer, it would appear desirable next summer to attempt to evaluate visibility in the terms of the NDRC nomographic charts, utilizing only sky brightness, target size and brightness, and measured attenuation coefficient data. Various availabel devices for measuring attenuation should be tested to ascertain whether the absolute thresholds obtained are predictable by the NDRC nomographs from the appropriate measurements.

Bo $\cong$ 1000 footlamberts

$\Delta E/Bo$ values

Observer	Laboratory NE	Laboratory 5X	Field NE	Field 5X	Tiffany data NE
DJB	2.64×10^{-9}	1.10×10^{-10}	1.46×10^{-9}		
PS	4.06×10^{-9}	1.79×10^{-10}	3.10×10^{-9}	3.09×10^{-10}	3.68×10^{-9}
	N = 522	N = 751	N = 120	N = 60	

Binocular gain = 23.1

Bo $\cong 5\times10^{-4}$ footlamberts

ΔE values

Observer	Laboratory NE	Laboratory 5X	Field NE	Field 5X	Tiffany data NE
DJB	2.29×10^{-9}	3.34×10^{-10}		1.68×10^{-10}	
PS	3.56×10^{-9}	3.40×10^{-10}	6.94×10^{-9}		1.10×10^{-9}
	N = 425	N = 541	N = 80	N = 80	

Binocular gain = 8.78

Average $\frac{\text{Field value}}{\text{Laboratory value}} \cong 1.14$

Table I

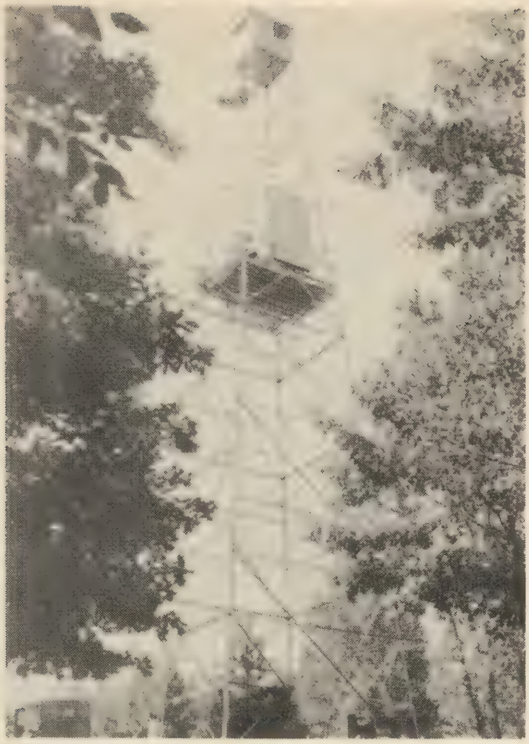

Figure 1

Figure 2

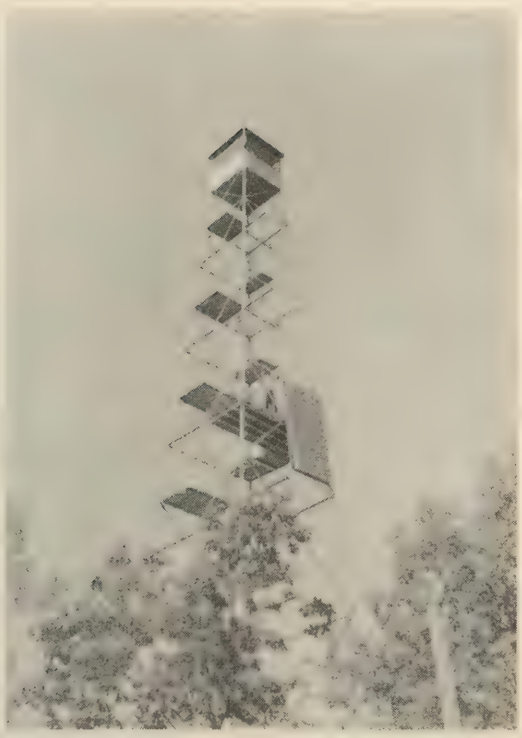

Figure 3

Figure 4

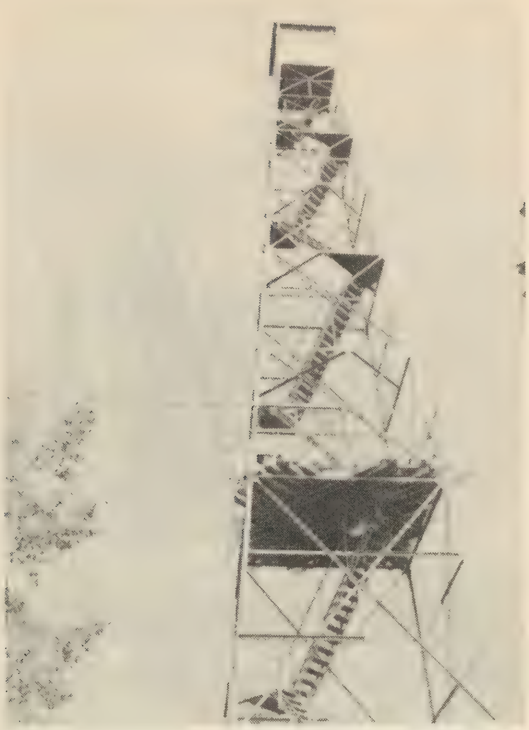

Figure 5

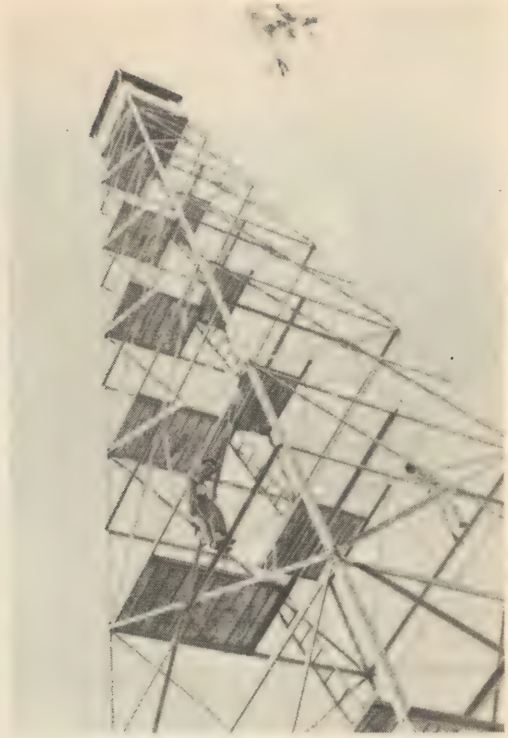

Figure 6

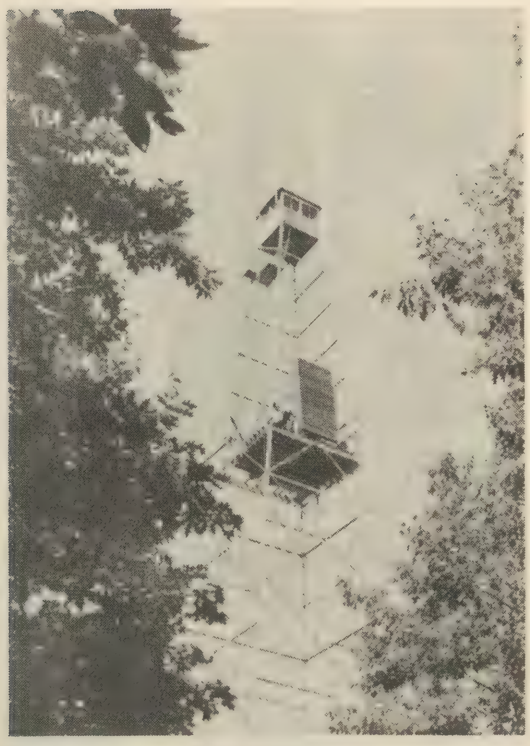

Figure 7

Figure 8

Figure 9

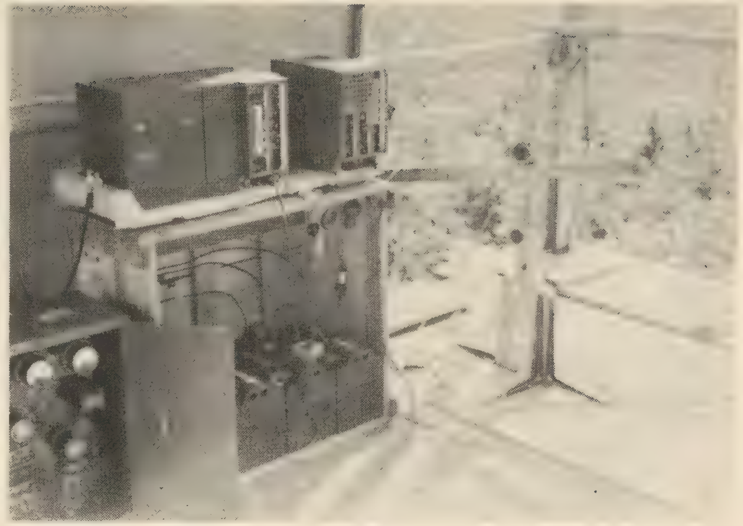

Figure 10

Figure 11

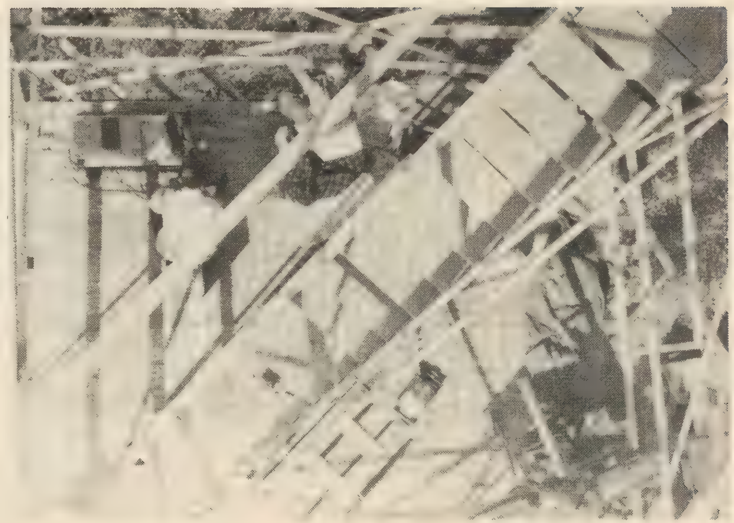

Figure 12

DISCUSSION:

In answer to a question from the floor concerning changes in color of the searchlight, Dr. Blackwell had to report that he had never observed any.

Dr. Dunham commented that the situation encountered during the Roscommon mission was very similar to what astronomers face when they look at stars and planets through the atmosphere. He suggested that the nature of the atmospheric fluctuations might best be determined by putting motion picture film at a point somewhat removed from the focal distance of the objective. In this case, the image on the film would yield a measure of the amplitude and frequency of the fluctuations in the atmosphere.

Dr. Blackwell reported that such a system had been tried in a preliminary way. A simple objective had been used which focused the image on the cornea of the eye. The eye was then used to view the appearance of the objective itself. If the atmosphere fluctuated, the lens was seen to vary from uniformly bright to uniformly dark over its entire surface. The rate of fluctuation of the appearance of the lens would given an excellent measure of the atmospheric fluctuations.

Dr. Dunham reported that experiments of this sort on a 100-power telescope used in observing stars showed variable wave length of the fluctuations of the atmosphere ranging from 4 inches to 100 inches.

Dr. Dunham questioned Dr. Blackwell's conclusion that the diffuser experiment indicated the atmosphere was not acting prismatically. Further discussion revealed that the criticalness of the diffuser experiment depended upon the location of the turbulence areas in the atmosphere, i.e., whether they were near the search light or near the eye.

Dr. Miles commented that while observing the motion pictures he had gained the impression that the vertical axis of the image of the searchlight tended to be more prolonged than the horizontal axis. He wondered whether such an effect might not result if the motion picture camera did not completely "stop" the action.

Dr. Blackwell reported that analyses of individual frames indicated more variation along oblique axes than along vertical or horizontal axes.

Dr. Miles then asked whether movement of the tower itself might not contribute somewhat to the fluctuation of the light source.

Dr. Blackwell replied that this source of fluctuation had been considered, and that it appeared highly unlikely that movement of the tower contributed anything to the fluctuations, particularly in view of the oblique axis along which the major portion of the fluctuations occurred.

Dr. Tousey commented that if you observe stars through binoculars, rotating the binoculars, the image of the star becomes a broken wavy line full of colors. He suggested that the same device could be used in observing search lights in order to see what sort of flicker there is.

COAST GUARD INTERESTS IN VISION

The Coast Guard interest in Vision problems stems from the basic legal functions and responsibilities of the Service. In broad terms these functions are:-

a) Marine Safety - to safeguard lives of passengers and crews who sail on Merchant Vessels flying American flag, thru insuring presence of adequate numbers of properly trained personnel, thru requiring that ships be structurally sea worthy, and thru assuring the presence of equipment which will prevent or reduce loss of life in case misfortune overtakes a vessel or boat.

b) Aids to Navigation - to operate and maintain an efficient, unified and simple system of aids to navigation sufficient for the needs of mariners to make navigation easy and safe. In the broadest sense the International Ice Patrol and the Ocean Station vessels operated by the Coast Guard are aids to navigation of ships and aircraft, although both these operations are prepared to rescue personnel as has been dramatically demonstrated.

c) Search, rescue and law enforcement, to locate and rescue persons, travelling on or over the seas adjacent to United States and its possessions, from positions of peril; to enforce certain laws of United States which by their nature require the operation of sea going vessels and/or aircraft. Examples of this law are: custom import laws, immigration laws (smuggling by vessel or aircraft), sponge fishing law, and pelagic sealing law.

In addition to these broad functions the Coast Guard must be prepared to function as part of the Navy in time of war. In this case the vision problems of the peace time Coast Guard, stemming from legal functions outlined above, are added to the vision problems of the naval service. While the Coast Guard must keep informed of vision problems as related to Naval Science at all times, this discussion will be confined to those problems directly related to the peace time functions of the Coast Guard.

Reviewing these functions, it is apparent that the first two, Marine Safety and Aids to Navigation, are primarily aimed at preventing maritime accidents and casualties. The third function reflects the fact, that in spite of all possible prevention measures, accidents will happen, hence, means for reducing loss of life are required.

In carrying out these functions the Coast Guard is interested, as are all the Services, in the physiological aspects of vision, i.e. various methods and standards of vision used for selecting personnel, and in the closely related field of illumination, i.e. providing proper lighting for the administrative and recreational visual task. The Coast Guard has done some interesting pioneer work based on the concept that ships lighting should consider the visual tasks to be performed on a rolling pitching vessel, the normal construction of ships, military and water tight integrity requirements, etc. rather than simply adapting industrial practices to shipboard use.

In the general aspects of operating ships, aircraft and motor vehicles, the Coast Guard again shares the interest of other services in the visibility of running lights, effectiveness of lookouts, markings of instruments and as to the best types of binoculars and sunglasses. Here, however, the fields of interest

start to diverge somewhat. While Army, Navy and Air Forces operations are based on a preparation for war and thus demand simulation of war time conditions and the evaluation of the problem in terms of wartime conditions, many of the Coast Guard problems must be evaluated in a peace time basis. For example let us consider night lookouts. In a military situation dark adaptation and a high degree of motivation are practicable. While the motivation of the peace time lookout can be improved somewhat by giving lookout a sense of responsibility, , this is far more difficult to achieve day after day in peace time conditions. Where dark adaptation can be demanded in a military situation in peace time it tends to disappear due to such things as use of deck lights to reduce hazards to personnel and other lighting for comfort or safety. Rather than attempting to reduce visibility of a ship, increasing its visibility with deck lights and running lights reduces the hazards of collision under many conditions. While the lookout is in general looking for brighter objects than in wartime, what is his effectiveness? Due to legal requirements and tradition, lookouts continue to be used, whether or not the ship is radar equipped. Are they sufficiently effective to justify the expenditure of man hours involved? Under the limitations noted, how can they be used most effectively?

In most situations search must proceed rescue although on our ocean station program planes having to make emergency landings are encouraged to eliminate search by ditching in vicinity of station vessel whenever possible.

Thus vision as related to search problems is of direct interest to the Coast Guard which almost daily is actively engaged in various types of search. Search is not only an essential forerunner of rescue but far more often search, by locating the object sought, establishes the safety of persons concerned and eliminates the potential need for rescue.

Search is conducted in Coast Guard by aircraft, ship and by boat. Whereas in a military search problem it is often possible to use considerable numbers of planes and ships, much more frequently in Coast Guard work search is carried out by single aircraft or ship. It is not that the Coast Guard does not use multiple unit searches but rather that a larger percentage of searches made are one unit searches. Thus Coast Guard is relatively more interested in single plane searches, single vessel searches and joint searches of one plane and one ship, than other services.

The objects sought in the most common searches give some insight in to the nature of the search problem in the Coast Guard. A most common search is for a fishing vessel or yacht which is unreported. Planes are usually employed although bad weather may require use of ships. Here problem is not only one of detection but also of identification, that is, reading name of boat sighted. Identification is more difficult than detection. Search for large vessels in distress. Here problem is at its simplest unless vessel sinks. Search for downed plane, liferafts, ship boats, persons in water with or without lifejackets. Emphasis here is on detection rather than identification. Search for icebergs, growlers, floating field ice. Here problem is both to detect and to identify.

In search problems it is necessary to reduce the meteorological visibility to effective visibility. Effective visibility considers the speed of plane or ship, the altitude of the plane, the meteorological visibility, the visibility of the object of the search, and the state of the sea.

The visibility of the object of the search cannot be directly determined by operating personnel and will vary under service conditions of a given object. Much work has been done on effective visibility. However, it would be desirable

to present this work in somewhat more useable terms, covering the common objects for which the searches are made.

The interrelation between radar search and visual search is of considerable interest. For large objects having good radar reflection, usual procedure is to rely on radar for detection of object and on visual means for identification of object. With poor radar reflectors and smaller objects the probability of detection by radar decreases and increased reliance must be placed on visual search. However, it would be desirable to know the probability of detection of such objects with simultaneous visual and radar search.

Night search for objects not detectable by radar, such as personnel in water, small icebergs, etc. is a continuing problem for Coast Guard. What are the relative advantages of a dark adapted lookout system versus use of illumination by search light or aerial flares?

Contrasted with the wartime search, in peace time it is desirable that searching craft itself have maximum visibility. Stimulating action on the part of survivors, such as use of smoke signal, etc. will increase the probability of detection and rescue.

Closely allied with the search problem is the problem of increasing the visibility of the objects of search. While it is not suggested that the AMERICA be painted international orange just in case she should some day be the object of a search, the Coast Guard in approving life saving equipment for use on merchant and private United States vessels and in specifying life saving equipment for Coast Guard craft is concerned with increasing the probability of detection of life saving equipment. While many factors enter into the design of life saving equipment, one of the most important is assuring that survivors can be sighted with reasonable probability under all weather conditions.

Problems which arise in this connection are those of color size, reflection, and contrast. The final problem in each case is cost. What is obtained for how much? It is not sufficient to know that one of one color is better than another, we need to know how much better in terms of probability of detection in order to evaluate the cost. These problems enter most directly into considerations of life jackets, water lights for marking position, life buoys, rafts, pyrotechnics for night and day use, signal lights, and life boat equipment.

In the aids to navigation field the Coast Guard encounters vision problems which diverge most widely from the field of interest of other services. The marine aids to navigation system of the United States utilizes electronic, acoustical and visual marks or guides for the mariner. While we are most concerned at this time with the visual aids it should be borne in mind that they are only a part of a system and that problems in connection with visual aids are considered in the light of the object of the system as a whole.

The simplest division of visual aid to navigation is into lighted and unlighted aids. Lighted aids include the powerful primary sea coast lights commonly called lighthouses, lighted beacons, lighted buoys and rough lights. Unlighted aids include unlighted buoys, day marks, day beacon and ranges. Except in a few cases all lighted aids in the day time serve the mariner as unlighted aids.

Both lighted and unlighted aids will be of the greatest use to the mariner if designed for maximum visibility. Thus it can be seen that the work of the vision committee is of greatest interest to the Coast Guard in connection with

aids to navigation.

However, one of the obstacles to fullest utilization of the scientific work on vision is the lack of a common language so that the findings of the laboratory may materialize in the structures and optics of our visual aids to navigation. Many of the terms used in vision, like any specialized branch of science, are not understood by the practical engineer who makes the decisions.

Many considerations enter into the design of a lighted aid to navigation. The ultimate object is to obtain an easily distinguishable light that can be seen a specified distance in clear weather. In order to distinguish a light, characteristics of time, color and intensity are utilized. To obtain a light which may be seen at a specified distance involves all the factors involved in the visibility of lights. A few of the most important of these are: transmission of the atmosphere, beam candlepower, thresholds of visbility of fixed lights of white, red and green, duration of flash. Beam candlepower or intensity depends on light source and optical system used. At present time acetylene and incandescent electric lamps are both in common use and most of the optical systems are various forms of Fresnel lenses. Recently some optical systems utilizing parabolic mirrors have been procured and the trend in the larger lights is to replace fresnel system with reflection system, in the smaller lights asymetrical fresnel lenses are now under trial.

Gas discharge lamps have not been used to date largely because of inherent low brightness. Gas discharge lamps are being studied for possible use particularly in flashing lights. Present practice is to limit shortest flash to 2 seconds. This is based on work of Blondel & Rey whose work considered flashes of .001 second and longer. A question has been raised as to whether flashes of the order of 10 microseconds repeated rapidly enough to give appearance of a steady light could be used both in flashing and steady aids to navigation to any practicable advantage.

Reliability of the light source is the most important consideration in all lighted aids. To obtain this reliability with incandescent lamps in many cases, particularly on buoys, it is necessary to use lamp changers which bring a new lamp into the focal point as soon as the old lamp fails.

While power consumption is of little importance in a large lighthouse which is connected to a public utility or with its own generator (largest lamp presently in use is 1500 watts), at unattended lights and in buoys the overall power consumption is of great importance. Discounting for the moment acetylene lights which have more practical advantages that first meets the eye, the power consumption of an unattended light must not only light the lamp but must also operate the timing device and the lamp changer. Obviously it is desirable on unattended lights to use the smallest practicable period of light.

Recently we have had rather heated discussions as to the possible merits of flashing incandescent lamps by condenser discharge instead of interrupting circuit by timers. The specific problem was a comparison of a small buoy in which about 400 volts was fed into a condenser. As condenser became changed relays connected condenser in series with a 120 volt 25 watt lamp producing a rather bright flash. The opposing view was that equal beam candlepower could be produced more economically by simply overvoltaging a 6 to 8 volt lamp and interrupting the lamp circuit. It is quite possible with either system to obtain beam candlepowers of the same order. However, there would be considerable difference in the shape of the time intensity curve.

It is desirable in order to evaluate what is meant by equal candlepower from stand point of visibility, to know if eye acts under these conditions as a perfect integrator and visibility is equal to product of intensity times or whether value of the peak intensity has any practical bearing on the visibility of the light. In connection with gas discharge tubes is there any practical merit in the fact that a shorter time is required to reach full brilliance and to become dark?

Work done on visual acuity of lights under atmospheric conditions is of particular interest in connection with range lights. Range lights usually consist of two lights placed at different heights on shore, on the extension of the channel axis. When the rear light appears directly above the front light the navigator knows he is in mid channel. At present time trials of various types of single unit range lights are in progress. One of these single unit range lights is designed to project white light down the channel axis and to show red or green if vessel deviates from the channel.

The use of radar, loran, and radio beacons has reduced somewhat the importance of long range high powered lights. However, due to their simplicity, ease of use and low cost to navigator, they will probably remain important and reliable navigational aids for the foreseeable future.

Unlighted aids to navigation are of many types. Many are simply structures designed primarily for display of lights. Incident to holding up the light they serve as valuable daymarks. Considerable attention has been given over the years to making these structure distinctive and easily identifiable which are practical elements of the vision problem. However, it appears that less attention has been given to the elements of brightness, color, width, contrast. It is generally accepted that the lights which they support have a greater night time visibility than the daylight visibility of the respective structures. While it is debatable as to whether we should strive for daylight visibility equal to the night time visibility, it would appear that the daylight visibility of light structures could be improved.

In some cases where visibility of light structure is low, targets are placed on the structure to improve the daytime visibility

In cases where volume of traffic does not warrant a light or where channels shift rapidly, day beacons are used. Many of these targets and day beacons are vertical panels in a single plane placed normal to visual line of sight. Occasionaly two intersecting vertical planes are use and quite often these targets are pyramidal in form. Shape of vertical target is usually square, rectangular, diamond shaped or circular, usually white in color with a central area of black. Size of targets has been determined principally by attempting to make target subtend 4.5 min of arc at the extreme useful range.

All unlighted buoys are daymarks and all lighted buoys serve as daymarks in daylight.

Although both lighted and unlighted aids to navigation serve as daymarks, and in contrast to the lights which have been rather carefully studied, rather less attention has been paid to applying basic principles of vision in a systematic manner to improve the daytime visibility of visual aids. Numerous individual aspects have been studied but due to the larger number of factors involved which have not been subject to quantitative evaluation in the past, present daylight aids are largely the result of accumulated practical experience.

Little attention has been focussed on the best possible utilization of the vertical components of daylight. As an example a vertical target facing east has a high brightness during the first few hours after sun rise and then decreases in brightness the rest of the day. Should the line of sight place this daymark almost in line with the setting sun it may become invisible. Silhouetting the target against the sky requires expensive tall towers. Equal visibility might be obtained by better utilization of incident light.

Use of paints to obtain best brightness has been on an emperical basis. Although the choice of color is largely restricted to red, white and black, except for Intercoastal Waterway where yellow is also used, a thorough study of color in relation to visibility might yield tangible improvements.

The shape and design of targets particularly of range marks might yield greater visibility if designed on the basis of scientific facts.

A particularly interesting problem is increasing the visibility of daymark and unlighted buoys under searchlight illumination. Various types of retroreflective materials are presently in use for this purpose, but quantitative data as to their relative effectiveness under various conditions is lacking.

In applying scientific principles and knowledge to practical use often conditions having no laboratory conterpart become determining or at least important factors in the final design. The best light source in an extremely efficient optical system may be useless if sufficient heat is not generated to keep lens free from sleet, and ice. An almost perfect daymark in summer may become invisible under heavy snow. A carefully selected color for a buoy may not be of much value if sea gulls and pelicans find the buoy a comfortable resting place. The reflector with the best optical qualities may prove irresistible to small boys having a bicycle at home.

However, it is believed that if the design stems from sound basic principles of vision evaluated as to the function the visual aid is to perform, that in the ultimate compromise with practical factors a more valuable visual aid to navigation will result.

MINUTES OF THE EXECUTIVE COMMITEE MEETING HELD OCTOBER 20, 1947

The Chairman called for discussion of the organization of the Committee in view of the present status of the Research and Development Board. After considerable discussion, it was voted unanimously that the Vision Committee retain its present organization under contract between the Office of Naval Research and the University of Michigan. Itis anticipated that ONR will request the Army Research and Development Division to carry half the cost of expenses of the Committee.

The Chairman called for a discussion of the reorganization of the Committee, necessitated by the reorganization of the Armed Forces. After discussion, it was unanimously voted that the name of the Committee be revised from Army-Navy-NRC Vision Committee to Armed Forces-NRC Vision Committee.

In view of the reconstituttion of the Committee, the Procedure for Operation was revised and approved as submitted below:

PROCEDURES FOR OPERATION OF THE ARMED FORCES-NRC VISION COMMITTEE

I. MEMBERSHIP.

There will be three classes of membership in the Armed Forces-NRC Vision Committee: Members, Liaison Members, and Associates.

A. Members. Each of the four constituting organizations, Army, Navy, Air Forces, and National Research Council, will appoint members to the Committee. In the case of the Army, the Navy, and the Air Forces, members will be appointed representing official service units. The exact number of these members will vary somewhat with the changing organizations of the Services; it is anticipated that not more than 15 members will be appointed from each organization. Alternate members will be designated in each case to serve for the members in their absence from Committee meetings

National Research Council members will be appointed on the basis of their individual competence and interest in the work of the Committee. The number of NRC members is not specified, except that it will not exceed the combined number of Army, Navy, and Air Forces members. In case of absence, an NRC member can designate a colleague to act in his stead. Traveling expenses incurred in connection with the work of the Committee will be reimbursed. It is understood that individuals employed primarily by industrial laboratories are not eligible to membership.

Members will be privileged to attend all meetings, receive all publications, and to have franchise in regard to any matters of business of the Committee.

B. Liaison Members. Governmental organizations or scientific societies interested in the work of the Committee may, upon request, be permitted to name liaison members to the Committee. Liaison members will be privileged to attend all meetings, receive all publications, and to have franchise in regard to any matters of business of the Committee. Initially, liaison members will be named by the Civil Aeronautics Administration, the U.S. Coast Guard, the National Bureau of Standards,

and the Inter-Society Color Council.

C. Associates. Selected individuals who are not members of the Vision Committee may be designated associates by action of the Executive Committee. The Executive Committee shall review and revise the list of associates on frequent occasions.

Associates will have the right to attend all scheduled meetings of the Vision Committee and to receive all unclassified publications of the Committee. Only upon invitation, however, will traveling expenses be reimbursed. It is understood that individuals employed primarily by industrial laboratories are not eligible for appointment as associates.

II. EXECUTIVE COMMITTEE.

The Executive Committee will consist of nine members: one will be appointed officially by each of the constituting organizations, the Army, the Navy, the Air Forces, and the National Research Council; four members will be elected from membership; and the Executive Secretary will serve ex officio.

Election to the Executive Committee will be by vote of all the members, for a term of two years, with rotation. Vacancies on the Executive Committee will be filled by action of the remaining members of the Executive Committee.

The Executive Committee is impowered to act for the Vision Committee subject to the referral of appropriate issues, and reporting of all decisions to the Committee.

III. OFFICERS.

The Chairman and the Deputy Chairman of the Vision Committee will be elected by the Executive Committee from the members of the Committee. Both officers will not be selected from the same constituting organization. The term of office will be two years.

The Executive Committee retains the right to require that Members or Liaison Members be officers of the Armed Services, or be professionally qualified in appropriate fields such as: physics, physiology, psychology, medicine, optometry, or engineering.

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The Chairman called for the election of Deputy Chairman of the Committee to replace Major E. A. Pinson, whose new assignment forced him to resign. Lt. Colonel E. N. Kirsten was elected as Deputy Chairman by unanimous vote of the Executive Committee.

The Chairman announced the resignation from the Executive Committee of Commander H. G. Dyke. Under the reorganized Executive Committee, four members at large were required. Present members elected to the Executive Committee included Captain C. W. Shilling, Dr. Walter R. Miles, and Dr. Edwin R. Henry. Dr. Richard G. Scobee was elected unanimously to the vacancy on the Executive Committee.

The Executive Committee voted to invite the following persons to become Associates on the Committee:

Dr. Walter Grether, Aero Medical Laboratory, Wright Field, Ohio
Dr. Louise Sloan, The Johns Hopkins School of Medicine, Baltimore, Md.
Dr. William Rowland, the Johns Hopkins School of Medicine, Baltimore, Md.
Dr. E. Parker Johnson, Bowdoin College, Brunswick, Maine
Dr. Gertrude Rand, Institute of Ophthalmology, The Presbyterian Hospital, N.Y.
Dr. LeGrande Hardy, Institute of Ophthalmology, The Presbyterian Hospital, N.Y.
Mr. Nathan Pulling, Biological Laboratories, Harvard University
Mr. J. E. Uhlaner, AGO, Department of the Army, The Pentagon, Wash. D.C.
Mr. Lawrence Karlin, AGO, Department of the Army, The Pentagon, Wash. D. C.
Major Lee Rostenberg, Port Chester, New York
Dr. B. J. Wolpaw, Cleveland, Ohio

Visual Research Sponsored by the
Special Deivces Center, ONR

Leonard C. Mead

As indicated in the title of this paper, the Special Devices Center itself does not carry on a visual research program at Sands Point. On the other hand, in order to effect the objectives of the Center, which you have just heard described by Commander Gayler, it is often necessary to solve various visual and optical problems. The administrative procedure is to establish a government contract with an outside research agency or educational institution whose personnel and facilities attack the problem at hand. It is the purpose of this paper to describe for you some of the research thus instigated which might be of interest to the Vision Committee.

The visual problems which face the Special Devices Center usually stem from either of two sources, namely, 1) the development of synthetic training devices, or 2) the design of visual equipment displays. In regard to trainer development, the visual requirement usually consists in the creation of an illusion which will give the trainee synthetically the appearance of a real tri-dimensional spatial situation. This problem has been particularly acute in the past with respect to flight trainers and gunnery trainers. Considering the visual (as distinguished from vestibular, tactual, and kinesthetic) cues which produce depth in the real situation; it is fairly easy to reproduce most of the monocular ones in a trainer. The cue used predominantly is retinal image size despite the fact that size per se is an ambiguous cue to distance if the true size is not known. In conjunction with other cues, however, such as aerial and linear perspective, relative motion, light distribution and superposition, some fairly realistic illusions have been manufactured even though the objects viewed were located on a flat surface.

Whether, and how, to introduce other factors which produce stereopsis are more complicated problems. In several of our trainers which utilize motion picture projection, the assumption is made that convergence and accommodation are unimportant cues (as indeed they would be in the real situation); the generally accepted view is that these factors do not operate at all past twenty feet and are relatively unimportant past ten feet. Thus the projection screen is located ten or more feet away from the observer in a number of our devices. The actual visual angle subtended by the screen, however, is usually much less than the angle which the projected scene would truly occupy. This circumstance has led to a research and development project at the James Handy Organization in Detroit in which it is proposed to use a quarter sphere screen and a single projection system which will fill a visual field of 180° x 90°. The present scheme is a combination lens and mirror arrangement; further development is under way for an all-glass direction projection system. Progress already achieved to date indicates that this 180° lens projection system is both possible and feasible. The scene viewed by the trainee (in this case a flexible gunner) is still, however, a motion picture projected on a smooth curved surface.

In order to introduce additional cues to depth as a substitute for actual binocular disparity, the Center has developed trainers in which the actual objects seen have true solidarity and are viewed through moving (zoom) lens systems or epidiascopes. During the tour which you are about to take there will be two devices of this type, the Torpedo and Rocket Attack Trainer (Device 14-B-3) and the Contact Flight Simulator (Device 14-L-2)./

The Torpedo and Rocket Attack Trainer utilizes a relative motion computer and

an optical system to produce the illusion of an attack on a surface vessel from an airplane. Aircraft attitude is fed to a relative motion computer which solves the motion problem existing between an attacking aircraft and a maneuvering target vessel. The relative motions are translated into mechnaical motions of a photographed seascape and ship model to reproduce, through an epidiascope, the optical effect of attack. The pilot sees before him, in a section of spherical mirror, a seascape and sky effect in natural color with the sea running in the wind. The wind direction is variable by the instructor. The pilot further sees before him a ship model, proceeding on a specific course and speed, whose range will vary with the aircraft's approach tactic. Every motion of the aircraft's stick, throttle and rudder will not only show on the instrument panel but will be translated into roll, pitch and yaw relative to the horizon in the optical illusion.

Even more ingenious and complex is the Contact Flight Simulator. In this device the visual illusion of flight in an F6F over land or water under contact flight conditions is produced. The actual terrain consists of a three dimensional colored relief map suspended in an inverted position on the ceiling. The aircraft cockpit is mounted on a cart which carries the optical viewing system, an aerodynamic computer and servo amplifiers. Level flight at a constant altitude is simulated by actual movement of the cart along the floor. Changes in altitude are produced by extending or telescoping of the periscope through which the pilot views the terrain. Although the eyepiece is called a binocular, there is no binocular disparity in the system. The field of view is a cone of 76° at the entrance pupil. A roll maneuver is simulated by means of a prism movement in the periscope. The characteristics of the system are such as to permit a climb of 30° and a dive of 90°. By personal experience the speaker can attest to the dominant role played by the eyes in the production of visceral experiences when diving straight down toward the earth.

A final apparatus which should attract your interest is the British Automobile Trainer. The first point to note is its great simplicity as compared to the two devices just described. Actually, we are just experimenting with this trainer at the present time and we ask you to overlook certain shortcomings produced by repeated wear and tear on the optical parts. What is of particular interest is the fact that engineering complexity may not always be necessary to produce effective visual illusions. We find that we are in great need of a set of basic tested principles which will help us in the creation of synthetic trainers. All too often we have left the engineer the job of figuring out how to create the perception desired; also there seems to be little carry-over from one engineering experience to another. Several of us here at Special Devices feel that a practical contribution to engineering art could be made by individuals such as are found in the Vision Committee if they would bring together some of the established principles of simulation. Certainly the field of synthetic training would profit immeasurably if our engineers could be kept abreast of the methods used in creating the striking visual illusions such as those developed at the Dartmouth Eye Institute and the contributions of, for example, Gestalt psychology to visual perception in particular. We feel fortunate at the present time to be able to enlist the services of Dr. Brian O'Brien and his staff at the Insitite of Optics of the University of Rochester in solving many of the knotty optical problems which are presented by operational simulation requirements.

We turn now to the second types of visual research which is of interest to the Special Devices Center. The impetus for research here derives from our interest in human engineering or the attempt to fit the machine to the psycho-physiological characteristics of its operator. Much of this work consists in

determing the optimal visual display which should be presented by military equipment. Such studies involve experimentation with the design of dials, scales, meters, scopes and other types of visual indicators as well as the determination of the most desirable brightness and hue of the ambient illumination.

For the progress that has been made in this area we are indebted mainly to the Systems Research group at the Johns Hopkins University. This contractor has conducted extensive studies of the visual factors which affect target visibility and detectability as presented on radar equipment and has made recommendations concerning methods and procedures for abetting detectability of radar signals, increasing speed of reading, and minimizing perceptual errors. Many of you are the recipients of their reports and are thus already familiar with their work on such items as the following: 1) perceptual problems in the use of a particular type of Plan Position Indicator in which the effects of quantity and quality of structuring of the perceptual field were determined on the accuracy and speed of target position estimations; 2) the greater value in numerous instances of counter-type indicators as compared to conventional dials; 3) the specification of optimal cathode ray tube bias level with respect to target visibility; and 4) the facilitating effect of an auditory signal on the detection of new target blips on a cathode ray tube. At the present time there are a number of experiments in progress which relate to the general problem of radar signal detectability; among the factors being investigated are the effects of target size, ambient illumination, dark adaptation, interval following target scan, antenna rotation speed, retinal position, knowledge of target location, and time and intensity variables. In addition to bringing to bear some of the classical visual data on the radar problem, the Hopkins group has made at least two noteworthy apparatus contributions, namely, a projection timer for visual research and a photomultiplier photometer for taking photometric data on very small targets.

The Applied Psychology Laboratory at Purdue University has just completed a study on the effect of instrument dial shape on legibility. In this experiment a tachistoscopic presentation was made of five different but common types of dials whose features were as much alike as possible except for overall shape. Significant differences in per cent of reading error were found between all five dials. In order of most to least legible, the dial shapes were as follows: open-window, round, semi-circular, horizontal and vertical. Incidental observations revealed that errors were most frequent at the ends of the horizontal and vertical scales, and that errors on all dial types were more frequent on "mid-division" than on "whole number" settings. The Purdue group are now engaged in further experiments on the design of numerals for counter-type instruments and the effects of brightness-contrast between task, surround and background areas on visual performance.

The Psychophysical Research Unit at Mount Holyoke College has been studying the accuracy and variability of bearing estimates presented on large display screens. It has been found that the average accuracy of estimation, even without a reference line, is surprisingly good; the addition of a reference line increases accuracy and decreases variability for a considerable distance on either side of the reference indicator. The practical conclusion is that only a small number of reference indications are required in order to gain adequate accuracy. We already know that a large number of dial markings will decrease speed of reading. Other conclusions of general interest are: 1) the length of the indicator has little effect on the accuracy and variability of the estimation; 2) only the tip of the indicator is needed in order to estimate accurately and with low variability; 3) the most accurate subject is four times more accurate than the least accurate and the most variable subject is 3.5 times more variable than the least variable; and 4) the absolute error of estimation for all subjects is 2.76 degrees. Further work by

this group is now in progress which will contribute to the general problem of visual indicator design.

The Biomechanics Division of the Psychological Corporation is now routinely called upon to make recommendations concerning the visual display which should be incorporated into new equipment components. At last we have achieved that condition of coordination which was so often desired but seldom achieved during World War II. It is gratifying to report that representatives of the Corporation now actually meet with the designers in the Bureau of Ordnance or Bureau of Ships (or with designers in their contractors' plants) at the very earliest design stages of engineering development. Up to the present time, the psychologists have spent most of their time recommending already established principles of visual display; it is anticipated, however, that actual research in this area will soon be instituted.

In the time available, one final problem can be presented. The Special Devices Center is in need of a more perfect system for simulating during flight the visibility conditions of instrument flying. Our latest blind flying device consisted of an amber plastic applied to the windfoil that give the instructor fairly adequate outside vision, and a blue goggle worn by the student which permitted instrument visibility but a blackout of objects outside the cockpit. For reasons which we need not go into here, we would like to either 1) revamp and improve the present system, or 2) develop a better arrangement utilizing an entirely different principle not yet conceived. Any advice or recommendations which the Vision Committee can give on this matter would be most gratefully received.

PROBLEMS OF INSTRUMENTATION ENCOUNTERED IN SUPERSONIC FLIGHT

Abstract of discussion by Lt. Commander George Hoover

Lt. Commander Hoover discussed the problems in instrumentation which will be encountered in supersonic flight. He began by demonstrating the extreme complexity of the usual instrument array, and made perfectly clear the impossibility of flying at supersonic speeds with such arrays of instruments.

He then introduced the philosophy that in most instances the pilot does not need to know the exact reading of a dial, but merely whether or not the dial reading is safe for the conditions of flight at which he finds himself. This philosophy leads immediately to a great simplification of instruments in which only an "all or none" indication is given. Several interesting displays of this sort were shown which would certainly simplify greatly problems of flight.

Lt. Commander Hoover then approached the problem of instrumentation for supersonic flight from a completely new direction. He began by asking what were the critical bits of information the pilot needed to have. He listed these as the altitude and attitude of the plane, the satisfactory performance of motors, and the location of the plane with respect to the goal. He showed an idealized panel in which all these things were shown the pilot in a way they could be appreciated in a single glance.

The problems of transforming present instrument information into the form ideal for supersonic flight, have of course not been solved.

* * * * * * * * * *

DISCUSSION:

Dr. Miles asked whether Lt. Commander Hoover cared to comment on the physiological affects of supersonic flight.

Lt. Commander Hoover replied that acceleration is one of the greatest problems. In answer to a question from the floor as to what would happen if there were a power failure at supersonic speed, Lt. Commander Hoover replied that under these conditions such acceleration would be present that it would mean instantaneous death to the pilot. He indicated possible solutions to this problem, including a self-propelled cockpit which gradually reduced the speed, thus eliminating the great acceleration.

Wing Commander Nelson questioned whether the Navy had considered the use of senses other than vision for supersonic flight.

Lt. Commander Hoover reported that they were indeed considering all senses, but that most of their thinking centered around vision.

PROBLEMS ENCOUNTERED IN THE USE OF SUNGLASSES BY MEMBERS OF

THE ARMED SERVICES

Abstract of outline by Mr. Arnold Court

Mr. Court described the interest of the Quartermaster General in the sunglasses problem. He indicated that the only question raised was one of the expected need for sunglasses in various areas of the world in various seasons. Quartermaster General's Corps is required to provide the proper supply for each region of the world for various seasons, and accordingly desire to know what the true requirements for sunglasses were as a function of time of year and geographic location.

Mr. Court also commented on the fact that at present each member of the Army is supplied one pair of sunglasses, the total cost to the Army exceeding $1,000,000 per year.

RECOMMENDATIONS FOR USE OF SUNGLASSES IN THE ARMED SERVICES

Alphonse Chapanis
Johns Hopkins University

INTRODUCTION:

This memorandum has been prepared by the writer at the request of Dr Walter R. Miles, Chairman of the Subcommittee on Sunglasses of the Army-Navy-NRC Vision Committee. It attempts to answer, in a preliminary way, five questions concerning the routine use of sunglasses by ordinary troops. These questions are contained in a letter, dated 4 June 1947, from the Office of the Quartermaster General to the Secretary of the Army-Navy-NRC Vision Committee. This memorandum is not a final, definitive answer to these problems; it is rather a preliminary report to provide the members of the subcommittee with a common basis for further discussion. The five questions are considered seriatim below:

Question 1: Is the need for sunglasses restricted to times when the sun is higher than a certain angle above the horizon?

The answer to this question is a flat "No". If an individual is walking or driving directly into the rising or setting sun, he many experience intolerable glare as long as the sun is above the horizon.

Question 2: Is the need for sunglasses restricted to areas of high surface reflectance such as snow, white sand, water, white buildings?

The answer to this question is also in the negative, Although it is probably true that most intolerable glare situations arise from the high surface reflectances of snow, sand, etc., the sun itself is a powerful source of illumination. If the sun falls within the visual field even for a relatively short time, it may leave an individual with annoying after-images and other subjective symptoms, even in the absence of reflection. Also hazy sky viewed from below, clouds banks viewed from above, and concrete pavements or on the highways and airfields.

Question 3: Is the wearing of sunglasses when not actually needed detrimental to eye health and efficiency?

The answer to this question has several ramifications.

a. Sunglasses which are optically imperfect may affect the seeing process. If, for example, the glasses contain surface imperfections and lens power, visual acuity may be seriously impaired. There is no evidence, however, that this type of defect has any permanent, harmful effect on the eye. Prismatic deviation in the glasses may result in difficulties in convergence with strain of the extra-ocular muscles. Headache and other painful symptoms may occur in this situation, but again there is little evidence that this produces permanent damage to the eyes. This aspect of the problem is not particularly serious since adequate optical standards for sunglasses are available. Lenses are not uncommonly unmatched in density.

b. Clinical observation seems to indicate that the habitual wearing of sunglasses may decrease an individual's tolerance to bright light. This observation, as far as the writer is aware, has not been verified experimentally.

c. Aside from the two points mentioned above, there is no evidence that the continual wearing of sunglasses affects the health of the eye.

d. The effect of sunglasses on the efficiency of the eye is probably best summarized in this fashion: If sunglasses reduce the effective brightness of the surroundings below 100 millilamberts, vision will be affected. If the effective brightness of objects seen through sunglasses is greater than this, vision is unimpaired. Experimental justification for this lies in the fact that intensity discrimination (1) contrast sensitivity (2) and visual acuity (3,4) are not significantly affected until brightness levels fall below this value. The above data are from laboratory experiments, but field data also support these findings. Thus, Hecht et al. (5) found in outdoor experiments that visual acuity was unimpaired when the subjects wore sunglasses which reduced the sky brightness (the background for these experiments) from 4000 to 500 millilamberts. On a less bright occasion, when the sunglasses reduced the sky brightness from 1000 to 125 mililamberts, visual acuity was reduced a small, but statistically significant, amount. In general, it is probably safe to say that if sunglasses are worn only under conditions of high illumination and high brightness, vision is not significantly affected.

Question 4: Should the wearing of sunglasses be made mandatory (prescribed article of uniform) under certain conditions? Prohibited under others?

a. Apropos of the answer to Questions 1, 2, and 3 above, the use of sunglasses should be prohibited before sunrise and after sunset.

b. There is now sufficient evidence to show that exposure to bright sunlight over prolonged periods affects dark adaptation a small, but statistically significant, amount (6,7). If troops are required to work at night, and if maximum efficiency at night is required, the wearing of sunglasses in sunlight should be mandatory.

c. There is also enough evidence to show that photo-ophthalmia frequently occurs in arctic regions when individuals have no ocular protection. This appears to be due primarily to the effects of ultra-violet radiation on the cornea and external eye. Repeated exposures, if they occur within 24 hours, have a cumulative effect and the condition is apt to be painful and distressing to the individual concerned (8,9). The wearing of sunglasses under arctic conditions should be mandatory, but the regulations should probably be written by the local medical officer in charge. In this way, regional and/or seasonal variation in sunlight and terrain could be taken into account.

d. The conditions specified in b and c are rather specialized and there still remains the problem of whether sunglasses should be worn under conditions of high brightness other than those mentioned above. We know that glare, under indoor conditions, may affect visual efficiency markedly (10). It seems reasonable to expect that similar findings would be obtained outdoors as well. Then, too, we must not ignore the general psychological factors of comfort and ease of seeing. These factors are, to be sure, difficult to assess experimentally but their reality must not therefore be denied. Non-photophobic individuals differ greatly in the amount of light they can tolerate (11). Brightnesses which are tolerable to some individuals may be very distressing to others. For this reason, the issue of sunglasses to troops in bright environments should be on an optional basis. If a soldier finds that he can get along without sunglasses and would rather not wear them, let it go at that. If, on the other hand, another soldier prefers to wear them, let him. The loss in visual efficiency will not be great as

long as he does not wear them under unreasonable conditions, e.g., after sunset, and the increase in his comfort may be considerable.

This, is not the sort of thing that can be solved by legislation. Soldiers are famous for "losing" items of equipment they don't want. If some don't want to wear sunglasses, they won't and shouldn't be forced to except under the specialized conditions cited above.

Question 5: Is it possible to develop a meter to determine the instantaneous need for sunglasses?

Soldiers in the field carry too much equipment around now and would not favor another object to carry. Besides, the whole idea seems to rest on an untenable assumption, i.e., that there is some range of illuminations which absolutely requires the use of sunglasses. We must remember the large individual differences in light tolerance. And even under arctic conditions an individual will experience dazzle and glare long before he receives a harmful dose of ultra-violet radiation. Soldiers know when to put their gloves on. Let them decide when they want to put on their sunglasses.

Summary. In general, the issue of sunglasses to ordinary troops should be on an optional basis. The wearing of sunglasses has become a fad in this country and many people wear sunglasses when they are not required. On the whole, this is no great problem. Really serious decrements in visual functioning do not occur until brightnesses and illuminations are drastically reduced from full daylight values. The eye, in short, performs well over a very large range of illuminations. Then, too, we must remember that most sunglasses are not very comfortable. Most people will not wear them unless the increased comfort due to reduction of illumination compensates for the discomfort and inconvenience of the glasses themselves.

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DISCUSSION:

Dr. Miles commented that the exact interest of the Quartermaster Corps in the problem of sunglasses had not been made clear to the Subcommittee and that perhaps some of the recommendations made were not fully appropriate.

Colonel Lowrey inquired as to the present Army specifications for sunglasses.

Mr. Rich reported that at present sunglasses lens must be polarizing with a specified transmission of 12%.

The question of the ultra-violet and infra-red cut-offs of the present sunglasses was raised from the floor.

Lt. Commander Farnsworth reported that the present plastic goggles did not provide adequate protection from the ultra-violet or infra-red. Various members of the Committee expressed astonishment because it was generally believed that the Army and Navy had acted upon recommendations from the Vision Committee concerning the use of plastic with adequate infra-red and ultra-violet cut-off.

Dr. Rowland asked the question of whether discomfort can be considered an adequate warning of retinal deamage due to high brightness.

Dr. Miles reported that in the case of a small stimulus, such as an electrical arc, discomfort is not a fair warning of damage to the eye. He commented further that with extended brightness sources such as are encountered in the arctic, perhaps discomfort is a warning of retinal damage.

Commander Brown made the point that in the arctic there is need for some kind of eye protection goggles at all times. He implied that this was an additional factor to be considered in the specification of sunglasses since the sun-goggles can well serve as an eye protection device. Commander Brown mentioned also the general problem of snow blindness.

Mr. Court replied that he was not concerned with snow-blindness. He felt that snow blindness arises from eye strain due to inadequate accommodation and convergence under conditions in which the entire visual field is practically uniformly bright. His concern was with physiological damage rather than with the temporary discomfort due to snow blindness.

The question was raised whether a meter to indicate necessity for sunglasses was not feasible.

Dr. Chapanis made the point that individual variations in sensitivity to light are of the order of 10 to 1 and that in view of such large individual differences, the use of a meter would be impractical.

Dr. Miles stated that he believed there was a need for goggles of higher density than the standard issue for use in the arctic. He stated further that a summary of data on sunglasses indicating the physiological and psychological factors should be prepared and placed in the hands of local medical officers who might advise the troops concerning the use of sunglasses.

It was the general consensus of opinion that if Mr. Court's questions were to be answered directly, a large-scale study would have to be made to determine sensitivity to light of the population under various conditions of illumination. On the basis of such data, together with visual data concerning the brightness conditions encountered, allocations of sunglasses in various regions for various seasons could be made.

187. Comparison of the Center-Versus-Leading Edge of the Target Pip in Range Determination by the VF Remote Radar Indicator.
A. L. Sweet and C. T. Morgan
Psychological Laboratory and Systems Research Field Laboratory of The Johns Hopkins University.
Memorandum report 166-I-25, 10 July 1947, 13 pp. (R)

Purpose "On the "B" scope of the VF indicator, it is possible to determine the range of ship targets by tracking either on the center or the leading edge of the pip. This is an investigation of differences in operator performance in ranging by the two methods.

The Experiments "Two experiments were performed. In both instances the stationary target signals, injected by a synthetic target generator, were sent through the SG radar to two VF indicators. In the first experiment, a target was detected simultaneously by the two VF indicators, both either using the leading edge or the center of pip method. The ranges of 100 targets were determined by each technique. In the second experiment, where a more accurate target generator was used, range measurements for each of the 200 target inputs were made with one VF calibrated to the center of the pip and the other to the leading edge.

Results "The data were mainly analyzed by computing the discrepancy between the target generator range settings and the ranges reported from the VFs. The results show that:

Agreement between Generator and VFs. "The center of pip method gave slightly greater agreement between generator input and VF indicator output. In the first experiment, the mean difference between leading edge ranging and generator input was -77 yards; for center of pip ranging, the mean difference was -61 yards. The respective discrepancies in the second experiment were -9 yards and -1 yard.

The Difference Between Ranging Methods "The difference in ranging between the two methods was due to the fact that the use of the leading edge method resulted in larger and more frequent range underestimations than with the center of pip technique.

Improvement of Target Generator "The target generator was greatly improved between the two experiments. In the first test, it contributed 98% of the total error variability. In the second experiment, the generator was the source of but 27% of the total error in the system.

Variability of VF Range Readings "The obtained probable error of normal VF reading variability was 17 yards. That is, 50% of the time, a VF reading by an experienced operator will be within the true value by plus or minus 17 yards, assuming no other source of error. With the operators taking special care in ranging, the probable error dropped to 11 yards.

Conclusion "In view of the slight superiority in favor of the center-of-pip method, a general rule, barring any special electronic or physical factors, would be to use the center of the echo in ranging on radar SG ship targets with the "B" scope of the VF indicator. This is in accordance with present Navy literature describing the operation of the VF indicator.*"

*Preliminary Instruction Book for Navy Model VF Radar Indicating Equipment - Bu Ships 288.

188. The Relative Efficiency of a Bearing Counter and Bearing Dial for Use with PPI Presentations.
A. Chapanis
Systems Research Field Laboratory of The Johns Hopkins University
Memorandum report 166-I-26, 1 August 1947, 21 pp. (R)

"In a continuation of earlier work on this problem, a direct-reading bearing counter was constructed and mounted on a VJ remote radar indicator so that this method of exhibiting the bearing of targets could be compared with that of the bearing dial normally used for the purpose. An experimental placement of the range counters, above the PPI and directly to the right of the bearing counter, was also tested.

"The first experiment measured the speed and accuracy with which radar operators can locate a target appearing on the PPI, adjust the bearing cursor and movable range rings to the position of the target, and read the bearing and range of the target from each of four different combinations of the bearing counter, bearing dial, and two range counters. The results show that, on the average, an operator can perform this sequence of operations 1.7 seconds (13.3 per cent) faster per target when he reads bearings from the counter rather than from the dial. There were fewer serious bearing errors in readings from the counter than in those from the dial. Further analysis of the data shows that the increased speed in performance with the bearing counter was not obtained at the expense of accuracy in operating the equipment.

"The second experiment compared the bearing counter and dial in terms of the speed with which settings could be reproduced on the two types of indicators. The bearing dial proved to be superior to the counter for this type of operation.

"Taken in conjunction with the data of the earlier study on this problem, these experiments indicate that a direct-reading counter is more efficient than an annular scale for presenting bearing information which must be read from an instrument. The counter-type indicator, however, is less efficient if settings must be reporduced or set into the equipment."

189. A Survey of the Importance and Use of Controls and Displays on Radar Console Panels (A. Contribution to Panel Layout).
K. O W. Sandberg and H. L. Lipschultz
Industrial Engineering Laboratory, New York University
Memorandum report 166-I-17, 20 July 1947, 21 pp (R)

"This investigation proposes that 'Importance' and 'Use (frequency and time)' be the basic criteria for establishing a sequence of priority considerations for the design and placement of controls and displays on the face of the radar console. This sequence would emphasize the early consideration of the more critical controls and displays in connection with a method of arranging them into more effective working areas for both reach and vision.

"Four methods of establishing an order of preference are considered and illustrated with an application to the SG-1b (mod. 50) radar. These methods involve: an analysis of procedure under different operating conditions; a simple analysis of one operating condition which includes times for elementary motion groups; two group interviews of thirty Navy personnel each; and a secret ballot of six other personnel.

"The survey, with small variation among the four methods, indicates that those controls and displays of the SG-1b radar which were considered of frequent and occasional use and of high and moderate importance are, in an approximate order of their rank, as follows:

Controls	Displays
Range Crank	"A" Scope
Bearing Crank (Manual)	Range Counter
Bearing Cursor Crank	PPI Scope
RPM Adjustment Knob	Relative-True Bearing Indicator
Range Step Toggle Switch	
Receiver Gain Knob	
Receiver Tune Knob	
Scale Selector Knob	
Sweep Expansion Knob	
IFF Toggle Switch	
IFF Gain Knob	
Anti-Jam Control Switches	

"In general, controls and displays important and useful to the technician or maintenance man should be relegated to positions of poor performance in the operator's working area."

190. Brightness of Grease Pencil Marks on a Vertical Plotting Board.
J. Gebhard and K. V. Newton
Systems Research Field Laboratory of The Johns Hopkins University
Memorandum report 166-I-23, 20 July 1947, 12 pp. (R)

"The brightness of marked and unmarked positions on two vertical edge-lit plotting boards was measured with a Macbeth Illuminometer. One board was a Square Knock-down type at the Field Laboratory, the other was a Mark 4 Mod. 1 modified by the removal of the rear sheet of plastic.

"The upper seven-eighths of the boards was quite evenly illuminated. Near the base, about eight inches from the lights, there was a sharp rise in brightness. Marks placed at the bottom of the board were about five or six times brighter than those near the top. On the Square Knock-down board the marks were about five times as bright as those on the modified Mark 4 board examined.

"China-marking pencils in white and yellow produced marks about 50-60 times as bright as the unmarked board. Other colors were relatively very dim.

"More light was reflected upward from a mark than in any other direction.

"If both sheets received the same amount of light from the lamps, marks placed on the front and rear of the board were about equally bright.

"The brightness of the lines etched into the plastic was about the same as a yellow grease pencil mark.

"A heavily marked up board contributed little to general room illumination.

"Over the range of 100 to 120VAC a change of one volt across the lamps produced a change in the brightness of a mark of about 0.5 apparent foot candles.

191. The Search Factor in Detecting Weak Radar Targets
S. B. Williams
Psychological Laboratory of The Johns Hopkins University
Memorandum report 166-I-28, 1 July 1947, 11 pp. (R)

"A laboratory investigation of the effect of size of area over which the radar operator searches for targets on the rapidity of detecting incoming targets is reported. The study was restricted to relatively large pips presented on PPI scopes. Furthermore, pips changed only in intensity from scan to scan and not in azimuth or range position. However, care was taken to control factors of psychological expectancy.

"Results of the investigation indicate that over very wide ranges of search area and for targets greater than ten degrees in lobe width there is no dependence of detectability on area of search, either for noise-free scopes or those cluttered with video noise. There is some evidence that for targets less than ten degrees in lobe width, however, area of search can be a significant, though relatively small factor in detectability, provided the target must be discriminated from a noise background.

"There are several implications of the present data for radar practice and for rational treatments of effective radar ranges insofar as they involve an expression for probability of detection. The question is raised whether overall probability of detection might not be increased by the simultaneous use of two or more operators on a given scope. If this should be a genuine problem, its method of resolution will turn, among other things, on the size of the area-of-search factor."

192. Accuracy and Variability of Direct Estimates of Bearing from Large Display Screens.
S. Rogers, J. Volkmann, T. W. Reese, and E. L. Kaufman
Psychophysical Research Unit, Department of Psychology and Education, Mt. Holyoke College, South Hadley, Mass.
Memorandum report 166-I-MHC1, 15 May 1947, 41 pp. (O)

"A series of studies of the estimation of bearing indicates that a surprising degree of accuracy can be attained when a large number of estimates are combined. This group accuracy can be attained without special training and without the aid of bearing markers, thanks to the fact that the normal individual has a fairly clear notion, under normal conditions, of the location of the vertical and horizontal and can, with somewhat reduced accuracy, make interpolations between them. Findings indicate that there is no appreciable difference between men and women in this respect.

"Individual accuracy and variability are relatively independent of the length of the line whose bearing is to be judged, and of its distance from the center of the display screen, but the introduction of a reference line or bearing marker increases the accuracy and lowers the variability of estimates. The stabilizing effect of such a reference line extends over a sufficient distance to suggest that a grid composed of a small number of lines might be sufficient to insure adequate accuracy. Presumably this would mean a saving in the time required for making the estimates, without sacrificing accuracy."

193. An Investigation of Corrective Training of Color Blindness.
D. Farnsworth
Medical Research Department, U. S. Submarine Base, New London, Conn.
Color Vision Report No. 15, 15 July 1947, 10 pp. (0)

The opinions of the foremost authorities on color vision in America were solicited and assembled in this report. The following conclusions were drawn by the author:

"1. The basic psycho-physiological functions, as indicated by luminosity curves, color mixture ratios and other stimulus data by which normal or defective color vision is described, are unaffected by medicine, training or other therapy.

"2. Practice and coaching will undoubtedly enable a color deficient person to pass, or to show an improved score on, an imperfect test.

"3. But there is no well established proof that training a person to pass a color-blind test contributes to rehabilitation in the true sense of the word, because the skills developed have no practical value except that of defeating the purpose of the screening test.

"4. The only aspect of color-blindness that can probably be modified by training methods is the ability to differentiate chromas, and the tests used for measuring improvement should concentrate on this aspect of the problem.

"5. Improvement measured by such means could not be interpreted as a claim to have made changes in the other and more basic aspects of color-blindness.

"6. A program formulated on these principles would also be of value in training persons with normal color vision to achieve a finer discrimination of colors."

194. Sight Line Deviation Measurements of B-29 Side and Upper Sighting Laminated Domes.
E. S. Barnes
Army Air Forces, Air Technical Service Command, Engineering Division, Armament Laboratory
Serial No. TSEPL-2-554-471, 31 March 1945, 30 pp. (R)

Line of sight deviation introduced by laminated domes for B-29 aircraft was measured. Procedures used and data obtained are presented in full.

195. Report on Conference on Bullet Resistant Glass Used as a Gun Sight Reflector Glass Held at the Libby-Owens-Ford Glass Co.
H. S. Goldberg
Army Air Forces, Materiel Command, Armament Laboratory
Serial No. ENG-53-554-312, 21 February 1944, 3 pp. (0)

"The purpose of this report is to make available information concerning the use of bullet resistant glass as a gun sight reflector glass and to report the conclusions reached at a conference on this subject held at the Libby-Owens-Ford Glass Company on 17 January 1944.

"It is believed desirable to use the bullet resistant glass in fighter airplanes as a gun sight reflector glass for the following reasons: The sight line can be raised while the sight body can be kept below the line of vision over the nose of the airplane. This will result in a larger angle of sight over the nose of the

airplane. The sight body can be mounted in such a manner so as to eliminate or reduce the crash hazard. The elimination of the thin reflector glass will also decrease the crash hazard. A reduction in the amount of glass the pilot must look through will increase his visibility for night fighting. Installations may be facilitated if the reflector glass were removed since less space will be required.

"It was concluded that bullet resistant glass of the type acceptable for use as a gun sight reflector glass can be produced in production quantities. The most satisfactory method of producing usable bullet resistant glass of this type is by grinding and polishing both surfaces. The difficulties which will be encountered in producing this type of glass make it necessary to recommend its use only in those cases where most of the above advantages can be gained."

196. Report on Conference on Bullet Resistant Glass Used as a Gun Sight Reflector Glass Held at the Libby-Owens Ford Glass Co.
H. S. Goldberg
Army Air Forces, Materiel Command, Armament Laboratory
Serial No. ENG-53-554-312, Add. 1, 20 March 1944, 2 pp. (0)

"The purpose of this amendment is to clarify the conclusions listed in the basic report. (Abstract no. 195, Basic memo dated February 21, 1944).

"Although acceptable bullet resistant glass of the type required can be manufactured, its use in a particular airplane depends upon the construction of the mounting means and the amount of deflection of the glass during flight. In order to reduce the sighting errors it is desirable to limit the sight line deviation due to canopy deflection to three (3) mils since the diameter of the central dot is more than two (2) mils. In order to assure that the use of bullet resistant glass as a gun sight reflector plate is satisfactory, in a particular installation, tests to determine the amount of sight line deflection during flight should be made. These tests should be in addition to the considerations discussed in the basic memorandum."

197. Effect of Source Size Upon Approach Light Performance.
G. M. Kevern
Army Air Forces, Air Materiel Command, Engineering Division, Equipment Laboratory,
Wright Field, Dayton, Ohio

The laboratory data on visual thresholds reported by H. R. Blackwell (J.O.S.A., 36, 624- 643, Nov. 1946) were used to ascertain the effect of size upon the efficiency of approach lights. It was found that approach lights used in fogs are not physiological "point sources" and that increased efficiency would result from reducing their size.

198. A Field Test of the Use of Filters in Penetrating Haze
W. S. Verplanck
U. S. Navy, Medical Research Department, U. S. Submarine Base, New London, Conn.
Bureau of Medicine and Surgery Research Project NM-011-003 (formerly X-638 (Av-330-p) and Bureau of Ordnance Project C-3515).

"In the discrimination of neutral targets, illuminated by the sun at various angles

of incidence, or by an evenly illuminated overcast sky and under a variety of visibility conditions, filters cutting off the short wave end of the spectrum show no effect of "haze-cutting". This result was obtained at a range of some 3.5 sea miles.

"Filters as dense as 1.00 log units (which reduce sky brightness to 10% of its full value) do not impair performance under any condition of visibility studied. Denser filters, whether neutral or red, may affect performance adversely to a slight extent.

"These conclusions are valid whether the eye is adapted to the filter or not; there is no indication of a specially favorable effect during the first few seconds of use of a filter."

Botler